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The Relationship Between Sleep and Memory in PTSD

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A minor dissertation submitted in partial fulfillment of the requirements for the award of the degree of Master of Arts in Psychological Research

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COMPULSORY DECLARATION
This work has not been previously submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation from the work, or works, of other people has been attributed, and has been cited and referenced.

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Abstract

Previous research has shown that in normal individuals sleep is critical to the formation of memories. Successful memory consolidation during sleep is contingent on the presence of slow-wave sleep (SWS), REM sleep and the successful transition of stages across the night. In PTSD, both sleep and memory processes are disrupted, but no previous study has examined whether these two variables are inter-related. This study aimed at determining whether disrupted sleep was a mechanism underlying declarative memory deficits in PTSD, investigating whether memory consolidation during sleep is disrupted in PTSD diagnosed individuals in comparison with controls. Participants were recruited to one of four groups – PTSD (n = 16), trauma-exposed non-PTSD (n = 15), depression (n = 15) and healthy controls (n = 14). After a screening interview, participants attended the Vincent Pallotti Hospital sleep laboratory for one night. On arrival, they completed several tasks measuring declarative and procedural memory performance. Declarative memory performance was assessed using a verbal paired associates task, story recall, and an autobiographical memory test. Procedural memory performance was measured using the finger tapping task (Walker et al., 2003). After memory tasks were completed, participants prepared for bed and went to sleep. Sleep variables such as total sleep time, sleep latency, number of awakenings, and percentage spent in REM and SWS were measured using sleep adapted EEG. Results were analysed using one-way ANOVA for sleep and memory variables and regression analysis with memory variables as the outcomes. Overall results show some support for the disruption of memory consolidation during sleep in PTSD.

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INTRODUCTION

Post-traumatic stress disorder (PTSD) is a debilitating disorder typically featuring key symptoms that occur in three clusters: re-experiencing symptoms (intrusive memories and thoughts); avoidance behaviours; and hyperarousal states (American Psychiatric Association, 2000). Associated with these clusters are specific cognitive and behavioural features, such as difficulty sleeping and difficulties with memory. Relatively little is known about how these symptoms, and the associated disruptions in cognition and behaviour, relate to and interact with each other. The currently proposed study will explore the relationship between disordered sleep and memory dysfunction in PTSD, and will argue that symptoms do not exist in isolation but influence each other.

Disordered Sleep in PTSD

According to the most recent revision of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; American Psychiatric Association, 2000), disordered sleep as a feature of PTSD may be categorized as a re-experiencing symptom (in the form of nightmares) and/or as a hyperarousal symptom (in the form of insomnia - the inability to fall asleep and to maintain sleep). Thus, disordered sleep is inherent to the diagnosis of PTSD. Furthermore, several research studies have shown that disordered sleep in the wake of a traumatic experience is often a predictor of the development of chronic PTSD (Harvey & Bryant, 1998; Koren, Arnon, Lavie, & Klein, 2002; Mellman, Bustamante, Fins, Pigeon, & Nolan, 2002). Given the prominence of sleep problems in PTSD, there has been a plethora of research to ascertain what exactly constitutes 'disordered sleep' within the diagnosis.

Subjective measures of sleep in PTSD. Subjective sleep reports from individuals diagnosed with PTSD suggest problems getting to sleep, maintaining sleep, and waking too early in the morning (Neylan, et al., 1998; Ohayon & Shapiro, 2000). These problems are consistent with the type of symptoms that typify the hyperarousal diagnostic cluster. Subjective reports also suggest that nightmares are more prevalent in individuals diagnosed with PTSD than in trauma-exposed individuals with no PTSD diagnosis and in healthy individuals (Krakow, et al., 2002; Neylan, et al., 1998; Ohayon & Shapiro, 2000). In PTSD, dream content varies from exact replicas of the trauma to thematically related dreams (Mellman, David, Bustamente, Torres, &

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Fins, 2001; Mellman, David, Kulick-Bell, Hebding, & Nolan, 1995; Schreuder, Klein, & Rooijmans, 2000; van der Kolk, Blitz, Burr, Sherry, & Hartmann, 1984), with some evidence to suggest that dreams that initially replicate the trauma exactly transform over time into deviations from the original event.

Although subjective reports suggest to researchers and clinicians what individuals with PTSD think about their sleep patterns, many studies have found that PTSD participants underestimate their overall sleep time and overestimate the time it takes them to fall asleep, resulting in far worse *reported* than *actual* sleep quality (Dagan, Zinger, & Lavie, 1997; Engdahl, Eberly, Hurwitz, Mahowald, & Blake, 2000; Hurwitz, Mahowald, Kuskowski, & Engdahl, 1998). Thus, objective measures of sleep are necessary to understand the nature of disordered sleep in PTSD.

Objective measures of sleep in PTSD. Objective measures of sleep are most commonly reported through polysomnography (PSG). The PSG uses a number of measures including electroencephalography (EEG), skin tone, eye movement, heart rate, and, sometimes, oxygen saturation and limb movement. A combination of EEG, measures of eye movement, skin tone, and heart rate allow for an objective report on sleep stages and on general sleep architecture.

Given the picture painted by subjective reports of sleep in PTSD, one might expect that objective measures of sleep in this disorder should feature a marked pattern of insomnia (both with difficulty falling asleep and maintaining sleep, as well as early morning awakenings) and disturbance from nightmares. However, studies report varied findings, many of which are inconsistent with these expectations.

Sleep architecture in PTSD. Normal adults sleep between 6-9 hours, with a generally stable sleep stage distribution. Time spent in stage 2 is 47-60%; 13-23% is spent in stages 3 and 4 (slow-wave sleep – SWS); and 20-25% in Rapid Eye Movement (REM) sleep. REM latency (the period before the onset of REM sleep) is typically 70-90 minutes, and time spent awake is usually less than 5% (Chokroverty, 2009a).

A number of researchers have found that individuals diagnosed with PTSD have poorer sleep quality than healthy controls. For instance, Mellman and colleagues (Mellman, Kulick-Bell, Ashlock, & Nolan, 1995b; Mellman, Kumar, Kulick-Bell, Kumar, & Nolan, 1995; Mellman, Nolan, Hebding, Kulick-Bell, & Dominguez, 1997) have reported that, in comparison to matched controls, Vietnam War veterans and victims of Hurricane Andrew with PTSD

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diagnoses showed more awakenings and increased night-time wakefulness. The PTSD groups' overall sleep efficiency (amount of time spent in sleep) was only slightly decreased relative to controls, however. Similarly, three studies by Lavie and his colleagues found significant differences in the sleeping patterns of individuals diagnosed with PTSD and healthy adults (Hefez, Metz, & Lavie, 1987; H. Kaminer & Lavie, 1991; Lavie, Hefez, Halperin, & Enoch, 1979). Specifically, PTSD participants had longer sleep latencies and decreased sleep efficiency. Dow, Kelsoe, & Gillin (1996) found that, in comparison to healthy controls, patients diagnosed with both PTSD and major depression, as well as patients diagnosed with major depression only, had reduced total sleep time and reduced sleep efficiency. More recently Germain & Nielsen (2003) also found that participants diagnosed with PTSD had more frequent arousals during sleep in comparison with other nightmare sufferers and with healthy controls.

Some of these studies have methodological problems, however. For example, two of the studies by Mellman and colleagues (Mellman, David, et al., 1995; Mellman, Kulick-Bell, Ashlock, & Nolan, 1995a; Mellman, Kumar, et al., 1995) included participants with substance abuse diagnoses. Other studies did not include adequate controls; for instance, Hefez, et al.(1987) only compared their PTSD data to estimates of healthy sleep architecture, while Mellman, Kumar, et al.(1995) only compared their PTSD data to those from healthy controls and did not include a trauma exposed non-PTSD group. In the latter case, it is difficult to answer the question of whether mere trauma exposure is sufficient for disrupted sleep, or whether an actual PTSD diagnosis in particular is associated with sleep disruption.

A small group of studies has found no differences in sleep architecture between individuals with PTSD and matched controls. For instance, Dagan et al. (1997) compared, using actigraphy[1] for a total of 5 nights per participant, the sleep of 16 male participants diagnosed with PTSD to that of 11 controls who had experienced the same war-related trauma. They found no between-group differences on measures of sleep duration, sleep efficiency, activity (amount of movement per minute), and number of sleep-wake transitions. However, actigraphy falls far short of the polysomnographic gold-standard in that it gives only a brush-stroke overview of sleep. Using actigraphy, one cannot determine the precise nature of events such as awakenings, their duration, and their spread over the night. More importantly actigraphy provides no details

[1] A techniques use to measure sleep/wake cycles and circadian rhythms using a device usually worn on the wrist.

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regarding sleep staging. Because some authors argue, for example, that PTSD is characterised by REM-disordered sleep (Pillar, Malhotra, & Lavie, 2000), a measure that does not accurately depict sleep stages has limited value in the PTSD-sleep discussion.

However not all studies reporting minimal differences between PTSD participants and controls have used actigraphy. For example, Engdahl et al. (2000) also showed no differences between a PTSD and trauma-exposed group using polysomnograph, except for increased REM density in the PTSD group. However, all participants in this study were elderly men (mean age of 71.3 years), which may limit the generalisability of the findings as elderly adults exhibit sleeping patterns markedly different from those of young and middle-aged adults. Similarly, Hurwitz et al. (1998) reported no statistically significant between-group differences on PSG measures, except for a lower arousal rate per hour in stage 3 and 4 in the PTSD group compared to a healthy control group. However, once again participants were older male veterans with a mean age of 45 and an age range of 38-63. Also, participants had a range of comorbid disorders (e.g., obsessive-compulsive disorder, alcohol abuse, and bipolar disorder); thus, results from this study must be interpreted with caution. Although Klein, Koren, Arnon, & Lavie (2002) also found no differences between PTSD and control groups on sleep measures, they only had a very small sample, with 8 PTSD participants and 6 controls. Furthermore, all four of these studies did not use adequate controls: Dagan, et al.(1997), Engdahl et al. (2000) and Klein et al.(2002) used trauma-exposed controls but no healthy control group, while Hurwitz et al. (1998) did not use a trauma-exposed non-PTSD group. In summary, then, methodological problems may account for the lack of statistically significant findings between PTSD and non-PTSD participants in these studies.

Slow-wave sleep in PTSD. Findings across studies with regard to SWS are varied. Fuller, Waters, & Scott (1994) studied 10 combat veterans with PTSD and 10 healthy controls. They found no between-group differences in stage 1 and 2 NREM sleep, REM sleep, total sleep time, sleep latency, REM latency or sleep efficiency. More pertinent with regard to SWS was that, although the number of nighttime awakenings did not differ between groups, their distribution was different. Specifically, individuals diagnosed with PTSD tended to wake early on in the sleep cycle, with an associated reduction in percentage of SWS (as these stages tend to occur earlier in the sleep cycle).

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Kramer and Kinney (1988) also found that for PTSD participants the majority of awakenings happened during the first half of the night, thus disrupting SWS. Interestingly, they also found that the majority (84%) of trauma-related dreams also occurred during this period, particularly during the Non-Rapid Eye Movement (NREM) stage. These data confirmed those presented by Van der Kolk et al. (1984). Glaubman, Mikulinger, Porat, Wasserman, and Birger (1990) also found that SWS was significantly disrupted in individuals diagnosed with PTSD. On the basis of these data, they theorized that SWS was the primary sleep disruption in PTSD.

Other authors in more recent studies have found differences in SWS between PTSD groups and controls such as Yetkin, Aydin and Ozgen (2010). This study also showed that SWS was inversely correlated with the level of psychogenic amnesia implicating SWS in the consolidation of traumatic memory.

Other studies have found little difference in SWS between PTSD and non-PTSD participants or even increased SWS in PTSD. Mellman and his colleagues found no difference in SWS across their studies (Mellman, David, et al., 1995; Mellman, Kulick-Bell, et al., 1995a; Mellman, Kumar, et al., 1995; Mellman, et al., 1997). In contrast, however, Lavie and colleagues (Dagan, et al., 1997; H. Kaminer & Lavie, 1991; Lavie, et al., 1979; Lavie, Katz, Pillar, & Zinger, 1998) found across all their studies that PTSD participants had increased SWS in comparison to controls. Of particular interest is that they found that there was extreme variability in sleep stage distribution within their PTSD groups, with some participants showing extremely low SWS percentages and others showing high SWS percentages.

Overall, these findings highlight the inconsistency of data across single empirical studies in this research field. In an attempt to resolve this inconsistency and to impose some order on the field Kobayashi, Boarts, & Delahanty (2007) conducted a meta-analysis of 20 studies (including some of those reviewed above) chosen according to the following criteria: (i) inclusion of at least two study groups, one of which was a PTSD group, (ii) collection of PSG data, and (iii) exclusion of participants on any form of psychoactive medication. The meta-analysis focused on several moderating variables or covariates that studies had failed to control for including age, sex, depression and substance abuse to explain the inconsistencies across studies. Overall their study concluded that individuals diagnosed with PTSD had more stage 1 NREM and increased REM and REM density. They did not find any gross sleep architecture differences (such as sleep

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latency, time spent awake, but did not examine the frequency of arousals). Amongst their findings one of their main results showed that participants diagnosed with PTSD had less SWS.

REM sleep in PTSD. As in SWS sleep, the findings across studies of REM sleep in PTSD have been extremely varied. In these studies, the variables of interest have included the amount of REM sleep, latency to REM, density of REM (frequency of eye movements per REM time), and awakenings from REM.

Some studies have found that, in PTSD groups compared to non-PTSD groups, the amount of REM sleep is decreased (Glaubman, et al., 1990; Hefez, et al., 1987; Lavie, et al., 1979), while others have found that this amount is increased (Mellman, Kulick-Bell, et al., 1995a; Ross, et al., 1994). Similarly, some studies have found increased REM latency (often associated with decreased REM percentage) in PTSD, while other studies have found decreased REM latency in PTSD (Ross, et al., 1994).

In one study that investigated the characteristics of REM sleep in PTSD, Mellman, et al. (1997) compared 25 individuals diagnosed with PTSD with 16 depressed participants and 10 healthy controls. It is useful to compare PTSD to depression with specific reference to REM parameters as depression is characterised by decreased REM latency and increased REM (Franzen & Buysse, 2009). Mellman and colleagues reported that REM quantity was decreased in PTSD participants compared to depressed participants and to healthy controls. Interestingly, the PTSD group contained participants with both the highest and lowest values for REM latency. The researchers speculated that this situation arose because the pressure for REM to occur (which is natural in all humans) coexists in PTSD patients with hyperarousal (which tends to inhibit the onset of REM).

In summary, findings on REM sleep in PTSD are extremely varied. Some studies find increased REM percentage, while others find decreased REM percentage. Similarly, some studies report increased REM latency, while others reported decreased REM latency. However Kobayashi, et al.'s (2007) meta-analysis reported a small effect size of 0.19 indicating a small increase in REM across all studies. This result may reflect the comorbidity that PTSD shares with depression as depression is marked by increased REM percentage.

Some explanations regarding varied findings. As the review above indicates, findings across studies regarding PTSD and sleep have, in many respects, been variable; there are inconsistent reports in terms of gross sleep architecture, and in terms of SWS and REM

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parameters. Where there is consistency, however, is that most research seems to confirm the clinical and self-report observation that there is worse sleep in PTSD; in particular, many studies note a decrease in SWS.

There are at least two possible reasons for the identified discrepancies across studies. Firstly, as noted above, many of the studies suffer from methodological problems. In fact, the literature is difficult to organize and to systematize because of the methodological problems present in varying degrees across studies. Kobayashi, et al. (2007), in their meta-analytic review, found that age, sex, and comorbid depression and substance abuse were the variables most likely to confound data in these studies. For instance, with regard to the possible age confound, of the 20 studies included in their sample, 11 featured PTSD participants with a mean age over 40, the overall mean age of the entire PTSD sample was 42.4 years, indicating a heavy bias towards middle-aged and older adults. Confounds such as age may obscure some results (for example that of macro sleep architecture) or amplify certain findings – for example older adults in general display less SWS – so the overall decrease in SWS in the PTSD group may reflect the age related sample bias. In fact Kobayashi, et al. (2007) found that when the data were analysed for younger participants across the studies, no SWS differences were noted. In contrast the 'younger' sample (age < 42.4) showed a decrease in total sleep time, indicating changes in macro architecture.

With regard to the possible sex confound, 13 of the 20 studies in the meta-analysis used male participants only. With regard to the possible confound related to comorbid condition, 12 of the studies did not hold substance abuse as an exclusionary criterion. Further with regard to eligibility criteria, Kobayashi and colleagues noted that previous studies had not been consistent in applying criteria related to time since trauma (e.g., prisoner of war participants with time since trauma of 55 years (Engdahl, et al., 2000) to Vietnam War veterans with time since trauma of 25 years (Mellman, Kumar, et al., 1995) to Yom Kippur War veterans with time since trauma of 2-2.5 years (Lavie, et al., 1979))

An important design issue in this field, as noted earlier, is the inclusion of appropriate control groups. Many studies in the meta-analysis and in the field included either a healthy control group (see e.g., Fuller, et al., 1994; Hurwitz, et al., 1998; Mellman, Kumar, et al., 1995) or a trauma exposed non-PTSD group (see e.g., Dagan, et al., 1997; Engdahl, et al., 2000; Klein, et al., 2002), but not both. An ideal design would include both types of control groups, given that individuals who have experienced trauma may also exhibit pronounced sleep changes.

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Taken together, it is clear to see that these methodological issues have plagued more than three decades of sleep research in PTSD. There is a need for a new generation of studies that (i) include, at least, both a trauma exposed non-PTSD control group and a healthy control group, (ii) control for depression in some way, (iii) investigate adults who do not already have age-related sleep changes, (iv) control for the time since trauma, with a shorter time between trauma and participation being preferable, (v) include a representative group of women in the sample, and (vi) exclude individuals with a history of substance abuse disorders. In short, although Kobayashi et al.'s meta-analysis demonstrated that individuals diagnosed with PTSD have poorer than normal sleep quality, there is the need for more research that addresses the methodological shortcomings of previous studies to characterize, more precisely, the nature of disordered sleep in PTSD.

A second possible reason for some of the discrepancies in the results of previously published studies in this field is that there is actual variation inherent in the sleeping patterns of individuals diagnosed with PTSD. According to researchers such as Pillar, et al. (2000), individuals diagnosed with PTSD oscillate between a state of hyperarousal and the homeostatic pressure to sleep; that is, the increased arousal levels associated with their disorder keep them awake, but when they do fall asleep, they compensate for a previous lack of sleep by sleeping more deeply. Numerous studies on healthy individuals have shown that previously sleep-deprived individuals compensate by having increased SWS, increased REM, and decreased arousals when they do fall asleep (Chokroverty, 2009b).

In the PTSD-sleep research field, there is empirical support for the proposal that sleep patterns of individuals diagnosed with PTSD are variable. For example, Dagan et al. (1991) exposed PTSD participants and healthy matched controls to tones, using earphones, once they entered SWS. The tone increased gradually, in 5 dB increments. PTSD participants were harder to wake than controls, and the researchers suggested that this deeper sleep was associated with more disrupted sleep. Lavie et al. (1998) replicated the study for the REM sleep stage and found similar results: that is, PTSD participants were harder to wake than controls.

Studies related to the sleep deprivation hypothesis show that, at night, noradrenergic production is not diminished in individuals diagnosed with PTSD as it is in healthy individuals (Kosten, Mason, Giller, Ostroff, & Harkness, 1987; Mellman, Kumar, et al., 1995; Yehuda, Southwick, Giller, Ma, & Mason, 1992). This lack of noradrenergic reduction leads to a

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hyperarousal state with associated sleep-deprivation in PTSD individuals. Increased noradrenergic activity in the locus coeruleus is also associated with decreased REM sleep (Saki, 1991).

Hence, this theory postulates that individuals diagnosed with PTSD oscillate between increased and decreased REM and SWS as hyperarousal and compensatory mechanisms fluctuate. This theory not only has empirical support, but it is able to explain the variability in findings across sleep studies, and with regard to most of the major sleep variables, in PTSD; that is to say, the theory is able to account for the fact that there are great fluctuations in percentage of REM and SWS, REM latency, sleep onset and sleep efficiency, but that, overall, sleep quality and efficiency tend to be worse in PTSD participants.

In summary, findings with regard to the characteristics of sleep in PTSD are varied. Numerous previously published studies suffer from methodological problems that may limit the interpretation of their findings and their generalisability. Importantly, a meta-analysis of all major PTSD studies (Kobayashi, et al., 2007) showed that individuals diagnosed with PTSD have less SWS, more stage 1 NREM (lighter sleep), and increased REM percentage and REM density. The authors of that analysis acknowledged, however, that more methodologically sound single empirical studies are necessary in this field. To explain the cross-study variability in this field, some researchers (e.g., Pillar, et al., 2000) posit that increased hyperarousal and compensation are present in individuals diagnosed with PTSD (i.e., they do experience disordered sleep, but when they do fall asleep, they sleep more deeply than healthy individuals do).

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Disordered Memory in PTSD

A large body of literature demonstrates that PTSD is characterized by deficits in various aspects of memory. This review will focus on the PTSD-related deficits in verbal declarative memory[2] as these findings are most relevant to the understanding of memory formation during sleep, which will be discussed in the next section.

[2]Important distinctions between declarative and procedural memory are needed to understand what we mean by memory. Declarative memory refers to the retention of facts (semantic memory) and events (episodic memory), which are encoded quickly but can also be forgotten quickly. Anatomically, declarative memories are dependent on the hippocampal formation. In contrast, procedural memory is concerned with perceptual and motor skills. The

Almost all studies examining the performance of PTSD diagnosed individuals on tasks of declarative memory have noted deficits in this domain of cognitive functioning (Bremner, Randall, Scott, Bronen, et al., 1995; Bremner, et al., 1993; Gil, Calev, Greenberg, Kugelmass, & Lerer, 1990; Gilbertson, Gurvits, Lasko, Orr, & Pitman, 2001; Jenkins, Langlais, Delis, & Cohen, 1998; Vasterling, Brailey, Constans, & Sutker, 1998; Yehuda, et al., 1995). For example Bremner et al. (1993) found that both combat related and child abuse PTSD participants performed poorly on verbal but not visual memory tasks in comparison with healthy controls. Similarly Jenkins et al. (Jenkins, et al., 1998) found impaired verbal memory recall in rape survivors with PTSD in comparison with trauma exposed non-PTSD participants and controls. However some authors noted differences in verbal memory as well as attention (Uddo, Vasterling, Brailey, & Sutker, 1993). Deficits in attention can affect cognitive functioning globally – individuals who perform poorly on memory tasks and in addition have attentional difficulties may have poor memory as a product of their inability to concentrate.

To address this potential confound, Gilbertson et al. (2001) administered a battery of neuropsychological tests (including assessments of attention, memory, visuospatial constructive ability, and executive functioning) to 19 Vietnam veterans with PTSD and 13 without PTSD. Although veterans with PTSD reported higher depression scores and more substantial histories of alcohol abuse, only scores on tests of attention and memory provided unique and independent predictors of group membership. Most importantly here, memory performance was independent of attention performance and was not a secondary effect of impaired attention, and memory deficits were not significantly associated with level of depression or with past alcohol abuse. Also importantly, the findings reported in that study are specific to declarative memory performance – other studies have shown that no differences between individuals diagnosed with PTSD and controls exist on measures of procedural memory (Vasterling & Brailey, 2005).

Although memory deficits are separate from attentional difficulties in individuals diagnosed with PTSD, declarative memory is not a unitary concept and can be broken down into several domains, such as encoding (or initial learning), recall (the amount of information remembered after a longer period of time) and retention (the amount of information retained in comparison with encoding scores, often given as a percentage). Most studies in PTSD diagnosed

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latter is anatomically associated with cortico-striatal and cortico-cerebellar loops (Squire & Cohen, 1984; Tulving,

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individuals have found deficits in initial encoding in PTSD in comparison with controls. Although PTSD participants often show deficits in recall (Brandes, et al., 2002; Bremner, Randall, Scott, Capelli, et al., 1995; Bremner, et al., 1993; Gilbertson, et al., 2001; Jenkins, et al., 1998; Vasterling, et al., 1998; Vasterling, Brailey, & Sutker, 2000; Vasterling, et al., 2002), deficits in retention are seldom reported (Brandes, et al., 2002; Stein, Hanna, Vaerum, & Koverola, 1999; Stein, Kennedy, & Twamley, 2002; Sullivan, et al., 2003; Vasterling, et al., 1998; Vasterling, et al., 2000; Vasterling, et al., 2002) with the exception of Bremner, Randall, Scott, Capelli, et al.(1995; 1993). That is few studies have reported degradation of memory over time – individuals diagnosed with PTSD in comparison with controls seldom remember less after a period of time in comparison with what they initially encoded.

A number of methodological issues are noted in this body of research common to many areas of PTSD research. With the exception of a limited number of studies (e.g., Gilbertson, et al., 2001; Gurvits, Gilbertson, Lasko, Orr, & Pitman, 1997; Jenkins, et al., 1998) most studies have compared the PTSD group to a healthy control group and have not included a trauma exposed non-PTSD group. Although studies comparing trauma-exposure and PTSD reported that memory deficits are present in PTSD diagnosed individuals and not trauma-exposed individuals, this body of research remains fairly small making the distinction between trauma exposure and the psychological symptoms of trauma (PTSD) tentative. Secondly many of the studies have included participants with comorbid disorders as well as alcohol abuse. Although Gilbertson et al. (2001) found that memory performance was not related to depression or alcoholism in PTSD participants, most studies have not controlled for these possible confounds and the relative influence of depression and alcoholism on memory in PTSD remains uncertain. Further studies have not systematically controlled for comorbidity by using a patient control group (such as depressed group) or examined memory deficits between PTSD comorbid and PTSD non-comorbid groups (for example PTSD with and without depression) and have rather relied on statistical methods.

Further the neural mechanisms underlying declarative memory impairment in PTSD have provided a fertile ground for empirical research investigation. The hippocampus is the structure most commonly associated with memory (Squire, et al., 1992). Consistent with reports of

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1972).

declarative memory impairment in PTSD, researchers have found that hippocampal volume is reduced in many individuals diagnosed with PTSD (Bremner & Narayan, 1998; Bremner, et al., 1997; Bremner, et al., 2003; Gilbertson, et al., 2002; Smith, 2005; Villarreal, et al., 2002; Vythilingam, et al., 2005). Bremner and colleagues (Bremner, Krystal, Southwick, & Charney, 1995; Bremner, Randall, Scott, Bronen, et al., 1995) as well as Vythilingam, et al.(2005) also showed that decreased hippocampal volume was associated with verbal memory deficits. Furthermore, Werner et al. (2009) examined fMRI data of individuals diagnosed with PTSD during memory tasks and compared these to healthy controls. Although they did not find that memory performance was impaired in the PTSD group relative to the control group, they did find that between-group differences in the pattern of neural activation in the hippocampus and prefrontal areas. Specifically, participants in the PTSD group showed increased activation in the hippocampus and decreased activation in prefrontal areas during encoding. During retrieval, PTSD participants showed decreased activation, relative to controls, in the parahippocampal gyrus. Based on these data, the researchers concluded that, despite intact memory functioning, memory structures were not functioning normally in the PTSD participants.

In summary, this research shows that individuals diagnosed with PTSD perform worse on tasks of declarative memory, that this performance is correlated with the anatomically relevant hippocampal region of the brain (involved in encoding and retrieval of declarative memories), and that this area of the brain is smaller in individuals with PTSD.

Relating PTSD, Disordered Sleep, and Disordered Memory

Sleep is important for the consolidation of memory. For instance, numerous studies have shown that previously learnt information or procedures, and life experiences, are better remembered after sleep (Fischer, Hallschmid, Elsner, & Born, 2002; Gais, Plihal, Wagner, & Born, 2000; Marshall & Born, 2007; Rauchs, Desgranges, Foret, & Eustache, 2005; Stickgold, James, & Hobson, 2000; Walker, Brakefield, Hobson, & Stickgold, 2003). Furthermore, individuals with no additional training are able to remember more after a period of sleep than, for instance, those who have trained twice as much but have had no sleep in the period between learning and testing (Marshall & Born, 2007). After consecutive nights of sleep memory continues to be enhanced, despite no additional training (Maquet, 2001; Marshall & Born, 2007; Stickgold, 2005; Walker & Stickgold, 2004).

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Recently, researchers have investigated the specific effects of different sleep stages on different aspects of memory. In a pioneering study, Plihal and Born (1997) tested both procedural and declarative memory in 20 healthy men with reference to different sleep stages. Procedural memory was tested using a mirror-tracing task and declarative memory with paired-associate lists. Participants were woken on different nights after various sleep stages – in the middle of the night after predominantly SWS and in the early morning after predominantly REM sleep. A control group was used to test for memory recall while staying awake. The researchers found that declarative memory was enhanced by SWS and procedural memory by REM sleep.

Since then, a plethora of research has investigated the ways in which procedural and declarative memory might be supported by, or processed during, different sleep stage. Studies have shown, however, that the relationship 'SWS = declarative memory' and 'REM = procedural memory', otherwise known as the dual process theory, is not invariate. Some studies have shown, for instance, that declarative memory also benefits from late REM-rich sleep, and that procedural memory also benefits from early SWS-rich sleep (Marshall & Born, 2007; Rauchs, et al., 2005). Other researchers have argued that the marked memory consolidation effects of sleep are dependent on the orderly succession of NREM and REM sleep stages; this is known as the sequential memory processing theory (Marshall & Born, 2007; Rauchs, et al., 2005). Most researchers agree, however, that both these processes are important: that particularly but not exclusively SWS benefits declarative memory and that, similarly, REM sleep benefits procedural memory particularly but not exclusively. There is also some agreement that a sequential order of sleep stages is important for consolidation. Using these parameters, disordered sleep can be characterised as featuring either disrupted SWS or REM sleep, or as featuring an increase in awakenings and arousals, thereby disrupting the overall integrity of sleep stages.

Furthermore research has identified that during sleep the hippocampus is particularly active during SWS (Bodizs, Bekesy, Szucs, Barsi, & Halasz, 2002; Ji & Wilson, 2007; Louie & Wilson, 2001; Marshall & Born, 2007) and is responsible for the off-line processing of memory traces into stable representations. Researchers have hypothesized that for information to be stored long-term and not interfere with pre-existing memories, information needs to be stored in an intermediate buffer from which it can be transferred to long-term memory through off-line processes (Marshall & Born, 2007). Much evidence exists that the hippocampus and the medial

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temporal lobe act as the intermediate buffer, while the neocortex is the seat of long-term memories (Kali & Dayan, 2004).

Researchers have shown that sleep is the off-line processing time and more specifically that during SWS there is a constant dialogue between the hippocampus and the neocortex, theorized as the memory consolidation process (Marshall & Born, 2007). This dialogue is driven by slow oscillations (SWS) generated by the neocortex to organize the hippocampal-to-neocortical transfer of recent memories. The neocortex exerts top-down control over the firing of hippocampal neurons, with neocortical firing approximately 50ms ahead of hippocampal firing. However, during actual replay (firing of neurons that were involved in the encoding process) the hippocampus leads the reactivation in the visual cortex suggesting hippocampal-to-neocortical transfer of information (Ji & Wilson, 2007). Various electrophysiological signals such as sleep spindles and are representations of this process. This dialogue between the neocortex and hippocampus is said to underlie the memory consolidation process.

In summary, research into sleep stage-associated memory consolidation and into hippocampal activity during sleep emphasises the importance of sleep for successful memory consolidation. As noted in an earlier part of the review, declarative memory formation is impaired in PTSD, and this impairment is associated with smaller hippocampal volume and a different pattern of neural activation than in healthy controls. All of these various aspects of the PTSD research domain are relevant because the argument made in this study is that (a) the sleep-related memory consolidation process in individuals diagnosed with PTSD is compromised, and that (b) this dysfunction in the consolidation process helps explain why individuals diagnosed with PTSD struggle with declarative memory.

Because research into these theoretical links is in its infancy (for example, Yetkin, Aydin, and Ozgen (2010) only hint at the relationship between sleep and memory with the finding that SWS percentage is inversely correlated with psychogenic amnesia in PTSD), this study will only test whether sleep variables mediate declarative memory performance. Although the assumption here is that hippocampal functioning underlies this mediational relationship, it is beyond the scope of this study to actually test that assumption and to thereby firm up the theoretical links. Further the nature of this relationship will need clarification – is it that a previously damaged hippocampus is unable to perform sleep consolidation processes or that continual sleep disruption prevents adequate hippocampal processing or an interaction of the two? In short,

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what the current research sought to investigate was whether disordered sleep in PTSD has wider implications than just the inability to fall asleep and to maintain sleep.

Specific Aims and Hypotheses

Although the previously published body of literature is equivocal about what exactly constitutes disordered sleep in PTSD, this review has shown that many inconsistencies across studies are likely to be the product of methodological problems within those studies. In other words, it is fairly certain that PTSD is characterised by disordered sleep, but the exact nature of that disordered sleep is yet to be understood. Furthermore, the literature reviewed above suggests that (a) in PTSD, sleep is disordered, and, specifically, is marked by a decrease in SWS and perhaps by increased sleep latency, more awakenings, decreased sleep efficiency, as well as REM-associated changes such as decreased REM latency and increased REM and REM density; (b) successful memory consolidation is contingent upon intact REM and SWS stages and a preservation of regular sleep cycles through the night (viz., successful transitions through the stages of NREM and REM sleep marked by stable microarousals and infrequent awakenings); and (c) individuals diagnosed with PTSD experience marked declarative memory problems. No study thus far has, however, attempted to tease out whether disordered sleep might be a mechanism underlying memory problems in PTSD. To investigate this question, four groups (PTSD, trauma-exposed non-PTSD, depression, and healthy control) were compared to (a) determine the relationship between sleep and memory in PTSD, and (b) clarify the role of depression and trauma exposure in this relationship.

To begin to explore this proposed mechanism, the current study tested the following hypotheses:

1. PTSD participants, in comparison with all control groups, will have disordered sleep marked by (a) increased sleep latency, (b) more awakenings, (c) more time spent awake after falling asleep, (d) decreased sleep efficiency, (e) decreased SWS, and (f) REM changes.[3] No sleep research has examined the relationship between depression and trauma-exposure so no specific hypothesis can be stated regarding differences between these two groups. However, a priori strong prediction here is that healthy controls will

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have the better sleep quality than all of the other participants. Overall this hypothesis can be evaluated by PTSD < trauma-exposed ? depressed < control.

2. With regard to memory immediate recall and delayed recall:
    a. Participants who have experienced trauma will, regardless of whether they are carrying a PTSD diagnosis or not, perform more poorly than healthy controls on declarative memory tasks. Furthermore, participants with a PTSD diagnosis will perform more poorly than those in the other groups. Although the literature tentatively shows that memory deficits in PTSD are not explained by depression (and thus the PTSD group should perform worse than the depressed group), no specific hypotheses can be stated about how the depression group will compare to the trauma-exposed group at this stage. However, a strong a priori prediction here is that healthy controls will show the best performance on declarative memory measures.
    b. There will be no between-group differences on measures of procedural memory.

    Overall the relationship PTSD < trauma-exposed ? depressed < control will be evaluated.
3. With regard to measures of memory retention measures after sleep:
    a. Participants who have experienced trauma will, regardless of whether they are carrying a PTSD diagnosis or not, perform more poorly than healthy controls on declarative memory retention tasks. Furthermore, participants with a PTSD diagnosis will perform more poorly than those in the other groups. Although the literature tentatively shows that memory deficits in PTSD are not explained by depression (and thus the depression group should perform better than the PTSD group), no specific hypotheses can be stated about how the depression control group will compare to the trauma-exposed group at this stage. However, a strong prediction here is that healthy controls will show the best performance measures of declarative memory retention.
    b. There will be no between-groups differences on measures of procedural memory retention.

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[3] Overall the literature contains great variability with regard to REM changes, perhaps more so than the other sleep

Overall the relationship PTSD < trauma-exposed ? depressed < control will be evaluated.

4. Disordered sleep parameters will:
    a. predict poor declarative memory performance, and
    b. mediate the relationship between group membership and memory performance.

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variables, thus the direction of the REM change will be kept open.

METHODS

Participants

Participants (N = 60, all female) were recruited from Cape Town and its surrounding communities. They were recruited through local newspapers as well as branches of the Rape Crisis Centre in Athlone and Khayelitsha. With regard to individuals recruited in the latter way, I worked closely with counselors at the Rape Crisis Centres to identify potential participants. Participants were identified from past records based on their age and time of trauma described below. Once participants had been identified, counselors called each individual to obtain consent for me to contact them. Only then were potential participants contacted.

With regard to individuals who responded telephonically to advertisements placed in local newspapers, after answering the call I administered a number of short questions to ascertain basic demographic information (e.g., age) as well as previous history of trauma.

In total, 102 participants were screened, and 68 met the criteria for participation. Figure 1 summarises the reasons for exclusion of the remaining 34 participants. Eight initially eligible individuals chose to withdraw from participation after screening, leaving the final sample at N = 60. These participants were predominantly Xhosa- and Afrikaans-first language speakers, but all were fluent in English.

Based on the screening criteria outlined below, each participant was assigned to one of four groups: PTSD (n = 16), trauma-exposed non-PTSD (n = 15), depressed (n = 15), and healthy control (n = 14). Groups were matched in terms of age, IQ, level of education, and socio-economic status (represented by income). A series of one-way ANOVAs were conducted to ensure that there were no differences between groups for these variables (see Table 1). Chi-squared analysis was conducted for income as this was specified as a range (R0-R4999; R500-R999 etc – see Appendix A) and was analysed as a categorical variable.

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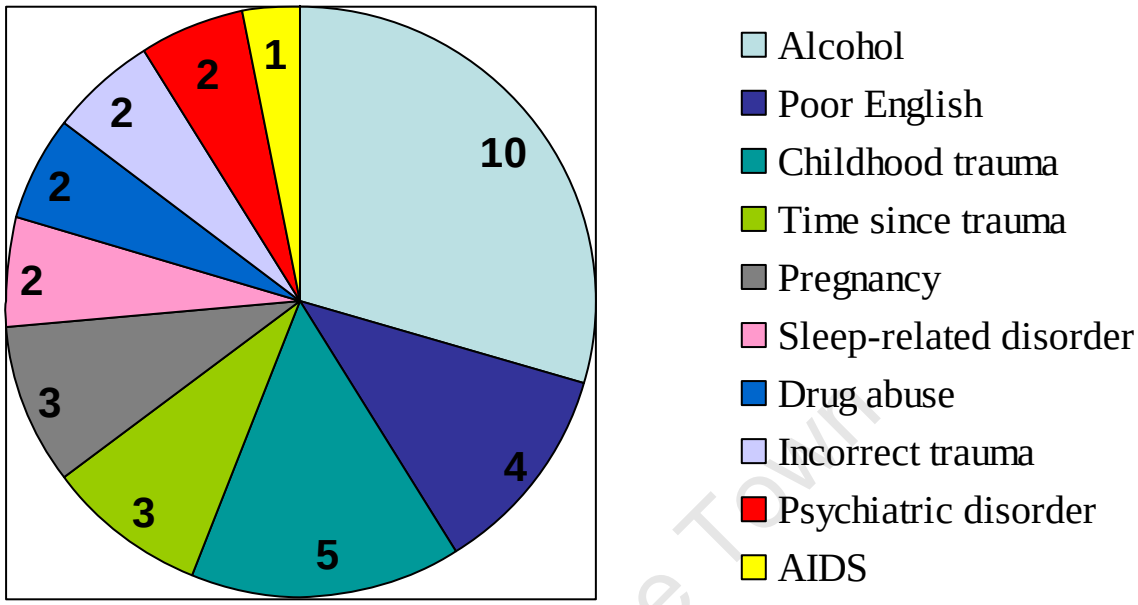

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Figure 1. Reasons for exclusion of 34 screened participants. Alcohol = participant met DSM-IV-TR criteria for an alcohol use disorder. Time since trauma = participant experienced traumatic event either less than 6 months or more than 5 years before screening. Sleep-related disorder = participant experienced a sleep disorder other than insomnia, such as REM behaviour disorder. Incorrect trauma = trauma other than rape. Psychiatric disorder = participant met DSM-IV-TR criteria for an Axis I or Axis II disorder other than PTSD, MDD, or a related anxiety disorder.

Table 1
Socio-Demographic and IQ Data for the Current Sample (N =60)

	Group					
Variable	PTSD (n = 16)	T-E non-PTSD (n = 15)	Depression (n = 15)	Healthy Control (n = 14)	F / χ^2	p
Age	26.71 (6.15)	25.76 (4.96)	27.13 (3.97)	27.17 (5.83)	0.237	.870
Years of Education	12.18 (2.19)	11.83 (1.11)	11.72 (1.57)	11.90 (1.04)	0.202	.894
WASI PIQ	82.73 (12.91)	77.79 (12.82)	82.34 (12.18)	84.00 (14.62)	0.657	.582
Income					21.50[a]	.255

Note. For Age, Years of Education, and PIQ, means are presented with standard deviations in parentheses. Degrees of freedom are (3, 56) for analyses of each of those variables. For Income, chi-squared statistic is presented as values were recorded as a range and coded as a categorical variable. WASI PIQ = Wechsler Abbreviated Scale of Intelligence Performance IQ score.
[a]$\chi^2(18)$ statistic reported.

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Inclusion and exclusion criteria. The following eligibility criteria were strictly enforced:

1. Potential participants diagnosed with any Axis I disorders except for the relevant PTSD and depressive disorders were excluded, as the sleep patterns and memory deficits characteristic of these disorders may serve as confounds (Harvey, Jones, & Schmidt, 2003). However, individuals in the PTSD and trauma-exposed non-PTSD groups who presented with other anxiety disorders secondary to the trauma were not excluded. In total across these two groups, 4 participants presented with panic disorder with agoraphobia, 2 with panic disorder without agoraphobia, 2 with agoraphobia only, and 4 with social phobia. Participants with no history of psychiatric disorders formed the healthy control group.
2. Potential participants with a previous history of alcohol or other substance abuse were excluded. Alcohol or other substance abuse is associated with both disordered sleep and memory dysfunction, and previous sleep studies have demonstrated the confounding effects of these variables (Stewart, Pihl, Conrod, & Dongier, 1998).
3. Potential participants below the age of 20 years and above the age of 40 years were excluded. Normal aging is associated with hippocampal atrophy, mild memory decline, and altered sleep cycles (Lupien, et al., 1994; McEwen, 1999), and the sleep cycles of children and adolescents differ from those of adults (Kales, et al., 1970)
4. Potential participants who were currently taking sedative medication to regulate their sleeping patterns, or who were prescribed psychoactive medication, were excluded. Sleeping pills alter natural sleep cycles, and psychoactive medications have demonstrable effects on memory processing and on brain structure and function (see e.g., Vermetten, Vythilingam, Southwick, Charney, & Bremner, 2003).
5. Participants who had experienced trauma more than 5 years or fewer than 6 months prior to screening were excluded. The proximity to the trauma has implications for both memory and sleeping patterns. For instance, potential participants in their early 20s who had experienced trauma more than 5 years ago may have experienced childhood trauma, which can affect the developmental trajectory of memory processing and have long-lasting implications for neuroendocrinological functioning (De Bellis, Hooper, & Sapia,

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2005). Hence, irrespective of the time since trauma, any participants who experienced trauma as children or teenagers were also excluded.

6. Participants who carried neurological conditions (e.g., epilepsy, traumatic brain injury) with the potential to influence the outcomes of the study were excluded. Five participants screened revealed that they were HIV-positive but did not present with any AIDS-related disorders and were regarded as asymptomatic (they had no weight loss, recurrent fever and opportunistic infections). AIDS is associated with HIV related dementia, while HIV alone is not. They were thus not excluded based purely on their HIV status.

Design

As noted in the Introduction, many previously published studies in this field suffer from serious methodological problems. To address those problems, the design of the current study sought to ensure that the type of trauma, the age of participants, and the time since trauma were all precisely specified.

Most studies of sleep and/or memory in PTSD have used war veterans in their sample. In fact, very few studies of PTSD-related sleep disorders have focused on forms of trauma other than war: In Harvey, Jones, and Schmidt's (2003) comprehensive review of studies up until 2003 only 3 out of 26 studies used participants who had experienced trauma that was not war-related. This focus on combat-related PTSD brings into question the generalisability of results to other populations. This point is especially important in a country such as South Africa, where the best predictors for a lifetime diagnosis of PTSD are, for women, rape and, for men, political detention and torture (D. Kaminer, Grimsrud, Myer, Stein, & Williams, 2008).

The combat veterans who form the large majority of participants in studies of sleep and/or memory in PTSD are almost always male, are mostly over the age of 50, and have typically experienced trauma between 15 and 50 years prior to being enrolled in the study. Each of these factors raises a methodological concern. With regard to the sex of the participants, there are clear differences between male and female physiological stress responses (Kirschbaum, Wust, & Hellhammer, 1992), and between the kinds of environmental and psychological stressors to which men and women are typically exposed (D. Kaminer, et al., 2008). Hence, although an ideal design would include both males and females, and enough of each to make

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sex-based comparisons viable, a more practical option is to include either only males or only females, and to include only individuals who have experienced the same type of trauma. The current study followed this practical option.

With regard to the age of participants, as noted earlier individuals over the age of 40 experience natural age-related changes with respect to memory and sleep (Blackman, 2000). Furthermore, children and adolescents experience cognitive changes associated with development which may influence memory performance as well as developmental sleep changes, including changes in sleep stage distribution through the night (Hoban, 2009). Hence, an ideal design would include only participants who might be characterized as young adults. The current study did so.

With regard to time since trauma, studies in this field rarely exert any between-subjects control over this factor. Harvey et al. (2003) state that the longer the gap between the occurrence of trauma and participation in the study, the more likely that factors other than PTSD may influence results. Hence, an ideal design would feature only participants who fall into a narrow range with regard to time since trauma. The current study did so.

By way of overview, here is how the current study addressed the methodological concerns highlighted above: All participants were females between the ages of 20 and 40 years, and all who were assigned to the trauma groups were rape survivors. All of the latter had experienced the traumatic event between 6 months and 5 years before the time of screening.

With regard to the inclusion of a control group that consisted only of participants with major depressive disorder (MDD), recent reviews of sleep studies in PTSD (Harvey, et al., 2003; Pillar, et al., 2000) have highlighted the importance of such a control. Depression is not only highly comorbid with PTSD, but also has its own specific pattern of disordered sleep, characterised by decreased SWS, decreased REM latency, and increased REM percentage (Franzen & Buysse, 2009). Furthermore, some studies have found that comparing PTSD participants to depressed controls has differentiated between disordered sleeping in PTSD and that in MDD. For instance, Mellman et al. (1997) found that their PTSD participants had decreased sleep efficiency and total sleep time, as well as an increased number of awakenings and a longer sleep latency, compared to both a depressed and a healthy control group. More recently, Yetkin, Aydin, and Ozgen (2010) found that individuals diagnosed with PTSD and

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concurrent depression had REM latency changes, whereas those diagnosed with only PTSD did not.

It should be noted, however, that some studies have found no significant sleep differences between depressed and PTSD patients. For instance, Woodward, Friedman, and Bliwise (1996) found that the only difference between individuals diagnosed with PTSD and those diagnosed with MDD was that the latter had significantly decreased SWS. Sleep latency and efficiency were normal in both groups. Thus, the relationship between PTSD and depression in terms of sleep quality and sleep characteristics is not clear-cut. Nevertheless, there is widespread agreement that there are disordered sleeping patterns associated with depression (Harvey, et al., 2003), and a well-designed study of sleep in PTSD needs to control for this factor, given the high rate of PTSD-MDD comorbidity. The current study addressed this methodological concern by including a depression-only control group.

Of note here is that, in the recruitment process, our research team found that only 4 of the 31 participants who met criteria for inclusion in the PTSD and trauma-exposed groups were not depressed. All 4 of these participants did not meet the diagnostic criteria for PTSD, and so were included in the trauma-exposed non-PTSD group.

In summary, then, the independent variable in this study was group status: PTSD, trauma exposed non-PTSD, healthy control, and depression. The dependent variables were performance on declarative and procedural memory tasks, as well sleep quality variables (sleep latency, sleep efficiency, number of awakenings, REM sleep percentage and SWS percentage). Essentially, this study investigated a mediational model testing the set of predictions that (a) those individuals who have developed PTSD in the aftermath of a severe trauma would perform worse on declarative, but not procedural, memory tasks, and that (b) part of the poor memory performance can be explained by the poor sleep quality of these individuals. In other words, the study examined whether, in PTSD, poor sleep mediates memory performance.

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Materials and Apparatus

Diagnostic and screening instruments. The *Mini International Neuropsychiatric Interview* (MINI version 5.0.0; Sheehan, et al., 1998) is a structured diagnostic interview that assesses the major DSM-IV Axis I psychiatric disorders. The MINI's developers report that the

instrument has good psychometric properties, and can be administered within approximately 15 minutes. The interview can be administered by either a clinician or a lay interviewer that has undergone the appropriate training. In the current study, this instrument was used to confirm diagnoses of PTSD and MDD, and to exclude the presence of other Axis I psychiatric conditions across all groups, with the exception of anxiety disorders secondary to the trauma in the PTSD and in the trauma-exposed non-PTSD groups. It was also the primary instrument used to determine selection of the healthy control group: These participants were required to carry no MINI-assessed psychiatric diagnoses, and were carefully screened to ensure that they had not experienced any events that qualified as a traumatic event under DSM-IV-TR PTSD criterion A.

The *Clinician Administered PTSD Scale* (CAPS; Blake, et al., 1995) is a structured interview designed to assess for the presence of core and associated PTSD symptoms. It is designed in such a way that individuals with little training in structured interviews, or with little clinical knowledge of PTSD, can provide reliable ratings of PTSD symptoms (Weathers, Keane, & Davidson, 2001). The CAPS assesses both intensity and frequency of symptoms by asking standard questions and utilizing an explicit, behaviourally-anchored rating scale. The instrument's developers indicate that it is a good indicator of PTSD severity, and that it has excellent reliability and validity for determining PTSD diagnoses (Blake, et al., 1995). In the current study, this instrument was used to validate the PTSD diagnosis provided initially by the MINI.

In terms of scoring, there are nine different ways of scoring the CAPS, all with good to excellent reliability (Weathers, et al., 2001). In this study, the *Frequency ≥ I / Intensity ≥2 / Total Severity ≥ 65 (F1/12/TSEV65)* method was used. This method combines two rules – the *Frequency ≥ I / Intensity ≥ 2 (F1/I2)* and the *Total Severity ≥ 65 (TSEV65)* rule. According to the first rule (F1/I2), a symptom is present if the frequency with which it occurs is scored as 1 or higher and the intensity is scored as 2 or higher. For a diagnosis of PTSD to be conferred upon an individual, DSM-IV criteria must be met in terms of the correct distribution of symptoms across clusters. This rule is considered lenient (Weathers, et al., 2001). The second rule (TSEV65) takes a total score of at least 65 as the basis for a valid diagnosis of PTSD and was derived as the optimal score for a PTSD diagnosis based on the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID; First, Spitzer, Gibbon, & Williams, 1997). This rule is

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considered moderately restrictive. Used together, these rules stipulate that a CAPS score of at least 65 must be reached for a diagnosis of PTSD to be made, and that there must be the appropriate distribution of symptoms across clusters.

This combined rule is considered reasonably stringent, and is recommended for application in situations where a diagnosis of PTSD is to be confirmed or a PTSD group needs to be homogenous (Weathers, et al., 2001). In the present study, both of these situations are applicable: the CAPS was used to confirm the MINI diagnosis, and, given the small sample size, homogenous groups were necessary to ensure the best possible results.

The *Beck Depression Inventory – Second Edition* (BDI-II; Beck, Steer, & Brown, 1996) is a standardized, 21-item, self-report questionnaire that assesses current presence and severity of depression in adults. The BDI-II is used both in clinical settings and as a research tool and its developers report that it has adequate reliability and validity. This instrument was used to help provide information about the level of depression reported by participants in the PTSD and trauma-exposed non- PTSD groups, as well as to characterise the depressive symptomatology of participants in the depression group. Participants with a BDI score of 14 or above and who met criteria for depression using the MINI formed the depression group.

The *Wechsler Abbreviated Scale of Intelligence* (WASI; The Psychological Corporation, 1999) is a short, four-subtest version of the Wechsler Adult Intelligence Scale (WAIS). Using the Vocabulary, Similarities, Block Design and Matrix Reasoning subtests, this instrument provides a reliable and valid estimate of WAIS Verbal, Performance and Full Scale IQ scores. The WASI takes approximately 30 minutes to complete and can be used with subjects from 6-89 years. It is used extensively in research that requires an overall IQ measure (see e.g., Saltzman, Weems, & Carrion, 2006). Because participants were not first-language English speakers and no appropriate and standardized translation is available, the Performance scale of this test was used as an estimate of general intellectual functioning to ensure that there were no major between-subject differences in terms of general cognitive ability. Performance IQ (PIQ) is a reliable estimate of Full Scale IQ (FSIQ); for the WASI, the correlation is reported to be 0.87 (The Psychological Corporation, 1999).

The *Michigan Alcoholism Screening Test* (MAST; Selzer, 1971) is designed to provide a consistent and quantifiable structured interview to detect alcoholism. It consists of 25 easily and

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quickly administered questions, and its developers report that it has good validity. This instrument was used to control for alcohol abuse as a possible source of disordered sleep and memory dysfunction. Potential participants with scores larger than 5 were excluded.

Experimental measures. Episodic memory performance was assessed using the V*erbal paired-associates* (*VPA* – Appendix B) task used by Lupien, Gillin, & Hauger (1999), which is similar to the one presented in the Wechsler Memory Scale – Third Revision (WMS-III; The Psychological Corporation, 1998). Participants were presented with a series of paired words, which they were informed they were required to learn. The words were read aloud to them by the experimenter, one pair at a time, with a period of 3 seconds between each pair. The word pairs were taken directly from Uttl, Graf, & Richter's (2002) "VPA15". This list contains 15 word pairs, of which four are regarded as "related/easy" pairs (e.g., *fruit-apple*) and 11 are regarded as "unrelated/difficult" pairs (e.g., *bank-milk*). The four "related/easy" word pairs and four of the "unrelated/difficult" pairs are taken directly from the Wechsler Memory Scale - Revised (WMS-R; Wechsler, 1987).

The list was presented to each participant twice, the second trial following immediately after the first. In each trial, the list was first presented using the "study order" provided by Uttl et al. (2002, p. 573), and then participants were required to engage in a cued recall task. This task involved the first word of each pair being presented in a random "recall order" (again based on Uttl et al., 2002, p. 573); the participant was required to give the second word of the relevant pair. The "study order" and the "recall order" differed from the first to the second trial.

The WMS-III *Logical Memory* subtest – *LM* - (WMS-III; The Psychological Corporation, 1998) was used to supplement episodic memory testing. This subtest was administered in the conventional fashion: Two stories were read to the participant, and, after each story, the examiner asked the participant to give an account of all the elements that she remembered from the story. A delayed recall trail is also assessed after the initial immediate recall.

The *Autobiographical Memory Test* (AMT - Appendix C; Williams & Broadbent, 1986) was used to assess the participant's ability to retrieve specific autobiographical memories, in response to a series of cue words with different emotional valences (positive, negative, and neutral). The version of the AMT used here drew closely on the original AMT paradigm in terms of the number and types of words used. A total of 15 cue-words were used: 5 positively-, 5

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negatively-, and 5 neutrally-valenced words. I examined only whether participants could recall a specific memory for a particular word within the given time limit. Two points were allocated for a response that met the criteria and that was produced in the first 30 seconds following presentation of the cue word, while 1 point was allocated for an appropriate response produced between 30 and 60 seconds following presentation of the cue word.

On this test, individuals diagnosed with PTSD typically produce responses that are overgeneral and do not refer to a specific memory (Constans, 2005). It is unknown, however, whether such overgenerality is related to disordered sleep in any way.

Procedural memory performance was assessed using the *Finger-Tapping Task* (*FTT*) described by Walker, Brakefield, Hobson, & Stickgold (2003). This is a procedural motor-skill computer-based task, programmed using E-Prime software (Version 1.1; Psychology Software PsychologySoftwareTools, 2002). It requires participants to type, using the non-dominant hand, a numeric sequence of five digits. The sequence of numbers appears at the top of the screen at all times to avoid reliance on working memory. Participants are required to type the sequence repeatedly, as accurately and as quickly as possible, for 30 seconds. In the current study, the task consisted of 12 such trials (the training session) separated by a 30-s fixation period. The primary outcome measure used here was speed (i.e., number of completed sequences within the given time limit). The first trial of the session was recorded as the baseline score, and the average score of the last three trials constituted the post-training performance.

At present I did not find any instrument to measure subjective sleep quality of sleep specifically in a sleep laboratory setting. Thus I asked 10 questions to ascertain the subjective sleep experience of participants in laboratory. The questions asked are featured in Appendix D with a rating added for some questions. Although this is not a standardized, validated instrument, it was used to provide some information about the subjective sleep experience of participants, particularly because only one night was recorded. A subjective report may offer some information about whether participants found the equipment irksome and the environment pleasant or unpleasant. A study by Hurwitz et al (1998) also used a non-standardized set of questions to evaluate subjective sleep the morning after a sleep study. This perhaps points to the need for a validated instrument for the measurement of subjective sleep after sleep-adapted EEG and polysomnograph.

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Sleep laboratory equipment. The study was set in a sleep laboratory, based at Vincent Pallotti Hospital, equipped with an electroencephalograph (EEG) adapted for sleep research. This equipment maps out sleep architecture and consists of EEG electrodes that measure brain activity, electrooculograph (EOG) electrodes that monitor eye movements, electromyograph (EMG) electrodes that measure muscle tone, and electrocardiograph (ECG) electrodes that measure heart beat. These different measures are essential in identifying REM sleep, as it is not always reliably identified through brain activity measures alone (Keenan, 2009). Sleep stages, as determined by the standard measurements of EEG, EOG, and EMG, were classified according to the latest specification provided by the American Academy of Sleep Medicine (2007).

For the sleep-adapted EEG recording I used a Nihon Kohden NeuroFax EEG9000 with sleep options. Our equipment met the requirements of all the digital system regulations (such as filters on each channel), the rules for display and display manipulation (such as the ability to view the sleep data in variable time frames, from 5 seconds to 2 minutes), as well as the digital analysis specifications (such as the ability to score the data either electronically or manually).

Our montage used the recommendations provided by the latest technical specifications manual of the American Academy of Sleep Medicine (AASM), released in 2007. However, it differed from a standard polysomnographic[4] reading in the following respects: Our montage did not record any of the respiration parameters (airflow, oximetry, nasal pressure, esophageal pressure, or rib cage or abdominal movements), leg movement or body position. For the purposes of this and other ongoing studies in our laboratory, we were interested in accurate determination of the various sleep stages, arousals, and sleep efficiency. The use of the measures not included is time-consuming, and because they do not formally address the core of our research questions, they were excluded from consideration.

In terms of the guidelines for electrode placements, we noted the following differences from the AASM standards: we used one more EEG electrode than the minimum specified by the AASM, we referenced[5] all our electrodes to a Z electrode placed in the centre of the forehead instead of the traditional M1 and M2 electrodes placed at the right and left earlobes, and we

[4]Polysomnograph refers to an EEG adapted to record sleep that contains all the channels and specifications provided by the AASM. Because our montage is based on the AASM but does not include an exact replica of the channels and specifications, we refer to it as an EEG adapted for sleep research.

[5] All electrodes need a reference – a signal to which the electrode makes reference.

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included an extra set of eye electrodes to supplement the two specified by the AASM. These changes were recommended to the research team by the equipment specialists to help us focus on accurately capturing the sleep stages, arousals, and overall sleep efficiency we were interested in determining.

Procedure

The study procedure included an initial screening phase, followed by a testing phase at the sleep laboratory. Only one night of sleep was recorded. Many previous studies have recorded at least two nights of sleep and discarded the first due to the first-night effect, where polysomnographic recordings show more awakenings and less REM sleep (Le Bon & Arpi, 2003). However, some recent studies have shown no differences in sleep architecture across two consecutive nights of sleep (see e.g., Sforza, Chapotot, Pigeau, & Buguet, 2008). One recent study examining individuals diagnosed with PTSD found no first-night effect for this population (Herbst, et al.). In summary, there is no consensus in the literature regarding the necessity of an adaptation night, but recent publications suggest that, if differences exist, they are minimal. Due to the time and cost associated with running an extra night for each participant, no adaptation night was included in the current study.

The first phase of the study, the *screening phase*, took place at Department of Psychiatry at UCT. Where necessary, transport was provided for participants. Each screening session began with the researcher explaining the aims and content of the research. Each participant read and signed a detailed informed consent document (see Appendix E), after which the screening measures listed above were administered

At the conclusion of these screening and diagnostic procedures, the researcher debriefed the participant about the study procedures to this point. If the participant was deemed suitable for continued enrolment, the experimenter scheduled an appointment for the sleep and memory testing night and assigned the participant to one of the four groups.

The second phase of the study, *the sleep and memory testing night*, took place at Vincent Pallotti Hospital sleep laboratory within 2 weeks after screening. On this night, the participant arrived at hospital at 20h00. I organized transport for participants to travel from their homes to the hospital using a local cab service. Upon arrival, each participant was briefed about the

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procedures for the evening and the morning. Participants were shown their rooms and provided with details about their environment, such as the use of the bathroom as well as emergency procedures should they require any assistance during the night.

The memory testing phase began thereafter. First, I read the two stories from the WMS-III Logical Memory subtest to the participants, and after each reading recorded an immediate recall score. Next, I administered the VPA task. At the conclusion of that task, I asked the participants to remember the stories and the word-lists because the recall tasks would be administered again in the morning. Finally with regard to memory testing, I administered the FTT.

Shortly thereafter, I prepared the participant for a night's sleep while attached to the adapted EEG equipment. More specifically, I attached the EEG electrodes to the head using collodion glue, and the EOG, EMG, and ECG electrodes to the face and chest using stickers designed for electrodes. Once the sleep equipment was set up, I tested that all the channels were working correctly by asking the participant to perform simple actions such as blinking and biting. I recorded the impedance (or amount of signal interference), to ensure that I was obtaining a clear reading. Participants were then given a final briefing about sleeping the night with the adapted EEG equipment; for example, they were assured that they could sleep in their normal body positions.

Participants were then allowed an 8-hour period of sleep, from approximately 22h00 until 06h00. After 8 hours, they were awoken and asked 10 questions (Appendix B) about their sleep quality on that night. After dressing and preparing for the day, each participant completed the morning testing phase: delayed recall for the WMS-III Logical Memory subtest, delayed recall of the VPA test, and the final set of FTT trials. Finally, I administered the AMT. All AMT responses were recorded via a dictaphone as well as in writing.

At the conclusion of the sleep and memory testing night, the participant was fully debriefed about the study procedures. Each was shown her sleeping patterns, with explanations about the various sleep stages; where appropriate, I briefed the participant about best practice regarding sleep hygiene. Each participant was then remunerated R150, and transported home.

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Ethical Considerations

Participants were given informed consent documents to fill out before being formally enrolled in the study. These documents ensured that they were fully informed about the study procedures and its risks and benefits, and provided them with the assurance that they could opt out at any stage of the study. Participants were assured that all their personal details would remain strictly confidential. They were also assured that the tests would not harm them in anyway and that they would be compensated for their time.

Because participants in the trauma groups were particularly vulnerable, and this vulnerability was particularly salient during the screening/interview session, where they were faced with relatively specific questions about previous exposure to traumatic events, participants were verbally assured at the beginning of each session that they could withdraw from the study at any point without penalty, and that that they did not have to give more details than they were comfortable with. Furthermore, participants who were struggling with PTSD or depression symptoms were referred to appropriate clinics and clinicians in their areas. At the conclusion of the study procedures, participants in the PTSD, trauma-exposed non-PTSD, and depression groups were provided with a list of trauma counselling centres and trauma counsellors.

All study procedures were approved by the Research Ethics Committees of the University of Cape Town's Department of Psychology and Faculty of Health Sciences.

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Statistical Analysis

Before statistical analyses were conducted on sleep variables, I scored the data according to the criteria of the AASM (2007). All record names and identification numbers were recoded so that I scored the sleep data blind to the group allocation of each participant. The UCT sleep research team attended numerous training sessions with Jan Top, a sleep technologist located at Panorama MediClinic, and with Marlene Gounder, the sleep technologist at Vincent Pallotti Hospital, to ensure reliable scoring of data. In addition, 25% of the records I scored were sent for validation to the Panorama MediClinic. These records were scored blind, with no knowledge of the participants' group allocation. An inter-rater reliability of 88.5% was calculated between me and the sleep technologist at Panorama MediClinic.

For the AMT, which requires an evaluation of the memory recalled by the participant as either specific or not specific, an inter-rater reliability of 93% was achieved between a trained independent rater and me.

The analysis began with an exploration of the data as well as the testing of assumptions that underlie inferential statistical analysis. This exploration gave an initial picture of the performance of all the participants, and of possible differences between the four groups.

Testing hypothesis 1. To examine between-group differences with respect to sleep variables, a series of one-way ANOVAs were performed on the measures of sleep latency, sleep efficiency, the number of awakenings, the number of spontaneous arousals, the number of minutes spent awake after sleep onset, SWS percentage, REM percentage, and REM latency. Significant omnibus ANOVA results were followed up with orthogonal planned comparisons to test where significant group differences lay. These comparisons are described below. Tukey's Honestly Significant Difference (HSD) post-hoc test was used to follow up on further group differences that the comparisons did not explain.

Testing hypotheses 2 and 3. Before analysis memory retention scores were calculated for the VPA, LM and FTT. This was done by taking the evening score and dividing it by the morning score and converting to a percentage. For the LM test, the manual provides scaled scores according to age for the percentage retention and these were used in statistical analyses.

To examine between-group differences with respect to memory performance (declarative and procedural memory encoding and recall, and declarative and procedural memory retention), a series of one-way ANOVAs were performed on test results from the VPA, LM, and FTT. AMT data were analysed using one-way ANOVA for autobiographical recall only, as this is the only domain assessed in this test. Similarly to the sleep variable analysis, significant omnibus results were analysed using planned comparisons and, if necessary, Tukey's HSD post-hoc test.

As noted above, three orthogonal planned comparisons were conducted to determine where significant group differences lay in the test of Hypotheses 1-3 (see Figure 2). To ensure that comparisons remained orthogonal, no comparison group was used more than once in the set of comparisons. This method ensures that there is no inflation in the familywise error: comparisons remain independent and thus the *p*-values are uncorrelated (Field, 2009).

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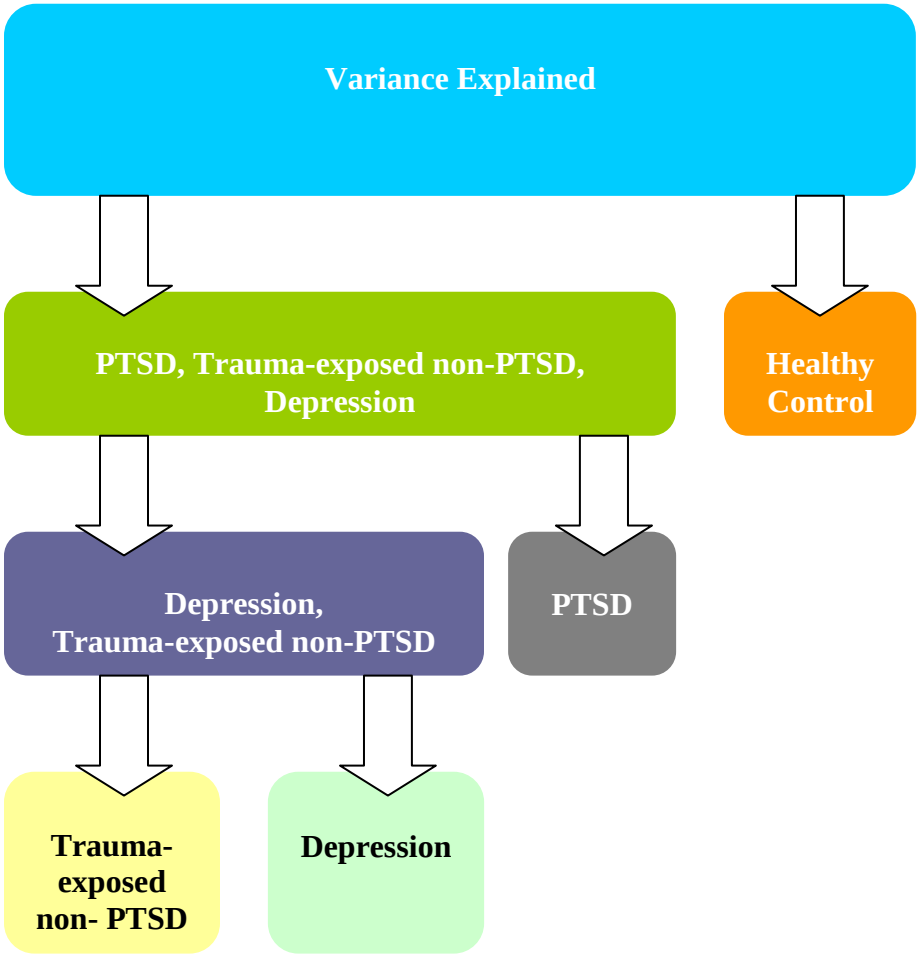

Figure 2. Schema showing the set of orthogonal planned comparisons conducted on data from the sleep variables and memory encoding, recall, and retention variables.

For the first comparison data from the healthy group were compared to those from the PTSD, trauma-exposed, depression and healthy control group taken together, since the latter three groups form patient samples, while the healthy control group is free from psychopathology. Further this comparison established whether the healthy control group had the best sleep patterns and memory performance as hypothesized.

At the second comparison data from PTSD group were compared to those from the trauma-exposed and depression group taken together to test whether PTSD participants performed worse than the other two groups and by implication worse than all the groups (testing whether the PTSD group performed worse than the two groups that performed worse than the healthy control group).

For the third comparison, data from the trauma-exposed non-PTSD group were compared those from the depression group. Although this comparison is not central to the aims of the study, it helped clarify the difference in terms of sleep quality and memory performance between trauma exposure, in a subsequent absence of PTSD, and depression. In the current sample, results from the screening measures showed that individuals in both these groups carry a MDD diagnosis; diagnostically, this is the major feature that they share. From this perspective, one might expect no difference between groups on sleep and memory measures provided the severity of depression is similar. However, the trauma-exposed individuals also exhibit PTSD symptoms that are sub-threshold, and so some group-level differences may arise because of that fact. In summary, then, this comparison will clarify to what extent these two groups are similar or different in terms of sleep quality and memory performance, allowing (along with the results from the other two planned contrasts) some insight into whether the shared characteristic of depressive symptomatology is as influential, in terms of sleep and memory, as the unique characteristic of trauma exposure.

Since the first and second planned comparison pooled together the scores of the PTSD, trauma-exposed non-PTSD and depression groups in the first comparison and the scores of the trauma-exposed non-PTSD and depression groups in the second, any further queries around the direction of significant results that the above planned comparisons could not answer, were tested using Tukey's HSD post-hoc test.

Testing hypothesis 4. To test whether sleep variables predicted memory performance and mediated group membership for memory performance, hierarchical regression was performed. Only memory variables that showed significant group differences were used as the dependent variables. Only the sleep variables that showed group differences were entered as predictors into the regression equations, so as to evaluate whether these variables mediated group membership for memory performance.

The statistical significance level was set at $\alpha = 0.05$ for all tests. All statistical analyses were completed using the Statistical Package for the Social Sciences, version 19 (IBM SPSS, 2011).

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RESULTS

Psychiatric Characteristics of the Sample

Data from the MINI, BDI, and CAPS were used to characterise the psychiatric conditions, symptom presentation, and symptom severity in the PTSD, trauma-exposed non-PTSD, and depression groups. Participants in the healthy control group were, by definition, free of any psychiatric disorders and free of traumatic experiences that would meet DSM-IV-TR criterion A of a PTSD diagnosis.

A *t*-test was conducted on CAPS scores to confirm that the PTSD participants had more severe trauma symptoms than the trauma-exposed non-PTSD participants. This prediction was confirmed, $t\ (29) = 7.94$, $p < 0.0001$ (PTSD: $M = 73.94$, $SD = 10.22$; trauma-exposed non-PTSD: $M = 36.27$, SD = 15.79).

In terms of depression, almost all participants in the PTSD and trauma-exposed non-PTSD groups met the BDI criteria for at least mild depression. Only four participants in the trauma-exposed non-PTSD group scored either 12 or 13, and thus almost exceeded the BDI cut-off for mild depression (14 or above).

In terms of severity of depression as measured by the BDI, a one-way ANOVA detected statistically significant between-group differences, $F\ (3, 56) = 32.07$, $p < 0.0001$. A planned orthogonal comparison was performed to analyse the direction of result. First, the healthy control group data were contrasted with those from all the other groups to confirm that the healthy controls were significantly less depressed than the other participants. Next, the PTSD group data were contrasted with those from the trauma-exposed non-PTSD and depression groups. Finally, data from the latter two groups were contrasted to each other.

As expected, the first contrast was statistically significant, $t\ (56) = 9.07$, $p < 0.0001$, healthy controls being far less depressed ($M = 5.07$, $SD = 4.78$) than the other participants ($M = 26.98$, $SD = 7.02$). In fact, the mean BDI score for healthy controls (< 14) indicated no presence of depression, which was expected. The second contrast was also statistically significant, $t\ (56) = 3.36$, $p < 0.001$; individuals diagnosed with PTSD were more depressed ($M = 32.31$, $SD = 8.03$) than the trauma-exposed non-PTSD and depression groups taken together ($M = 24.1$, $SD = 8.86$). This finding is consistent with previous research showing that more severe trauma symptoms are

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associated with greater depression (Weathers, et al., 2001). The third and final contrast assessed the difference in depression severity between the trauma-exposed non-PTSD and depression groups. There was no statistically significant between-group difference, t (56) = -1.35, p = 0.184. This finding suggests that these two groups were matched on depression severity. So, given that the primary clinical characteristic these two groups share is depression, it was of interest to examine how they differed with respect to sleep and memory variables. This interest was explored in subsequent analyses.

In summary, I confirmed that healthy control participants were not depressed, that participants in the PTSD group were more depressed than those in the trauma-exposed non-PTSD and depression groups, and that there was no difference in depression severity between the trauma-exposed non-PTSD and depression groups.

As noted earlier, one methodological problem present in previously published studies is that there were large within- and between-study inconsistencies in terms of time between trauma experience and study participation. To address this problem, I attempted to control time since trauma via recruitment in the design of the current study. This measure was successful: a one-way ANOVA comparing time since trauma in the PTSD group versus that in the trauma-exposed non-PTSD group detected no significant differences, F(1, 29) = 1.55, p = 0.224. Hence, there was no need to use time since trauma as a covariate in subsequent analyses.

Testing Hypothesis 1: Between-group sleep differences

Sleep data: Testing assumptions. After scoring and validation of the sleep data was complete, the assumptions underlying parametric statistical analyses (viz., normality of distribution of data and homogeneity of variance) were tested for all relevant sleep-related outcome variables: sleep latency, sleep efficiency, number of awakenings (defined as a period longer than 1.5 minutes after sleep onset (Chokroverty, 2009a), number of spontaneous arousals (defined as a period of abrupt EEG shift during the night, usually an increase in EEG frequency, lasting at least 3 or more seconds), time awake after sleep onset, percentage of SWS, percentage of REM sleep, and REM latency. Both the number of awakenings and the number of spontaneous arousals were analysed because these represent two different kinds of changes in consciousness and may occur with different frequencies between groups (Chokroverty, 2009a).

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An analysis of normality of data distribution using the Kolmogorov-Smirnov test (see Table 2) revealed that the data for only three variables (SWS percentage, REM percentage, and number of spontaneous arousals) were normally distributed. A more fine-grained analysis revealed that each group's data was normally distributed for these variables; such an analysis was necessary because, given that subsequent analyses will compare groups, what is important is not the distribution of the overall dataset for that variable but the distribution in each group (Field, 2009).

Although all the other sleep-related variables violated the assumption of normality, many of these variables (in particular sleep latency, sleep efficiency, time awake after sleep onset, and REM latency) have well-defined values for normal individuals; that is, their distributions are expected to be non-normal. More specifically, a healthy adult will generally take about 10 minutes to fall asleep, will have 95 percent sleep efficiency, will spend only about 20 minutes awake during the night, and will take about 90 minutes to reach REM (Chokroverty, 2009a). Although there is some variation in sleeping patterns across individuals, these values are determined by homeostatic processes and circadian rhythms, and are thus fairly stable. As indicated by the overall histograms for these variables (see Appendix F), the frequencies observed in the current dataset cluster around these well-defined "normal" values.

For the number of awakenings expected during the night there are not such well-defined values, so I did not expect a particular pattern of skewness. On fine-grained within-group analysis, it was only the frequencies of the trauma-exposed non-PTSD group that violated normality.

Another important note here, and something that is easily seen in Table 2, is that the data from the PTSD and trauma-exposed non-PTSD groups were much more likely to violate the assumption of normality than were the data from the depression and healthy control groups. This pattern indicates that there was greater variation and irregularity in the scores for the PTSD and trauma-exposed non-PTSD groups.

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Table 2
Sleep-Related Variables: Results for the Kolmogorov-Smirnov test of normality

	Group			
Variable	PTSD (n = 16)	T-E non-PTSD (n = 15)	Depression (n = 15)	Healthy control (n = 14)
Sleep latency	< .001***	.004**	.114	.200
Sleep efficiency	.030*	.018	.116	.098
Number of awakenings	.163	.025*	.081	.104
Number of spontaneous arousals	.200	.186	.200	.200
Waking minutes post sleep onset	.026*	.019*	.067	.088
SWS percentage	.200	.150	.200	.200
REM percentage	.200	.192	.200	.200
REM latency	.107	.005**	.200	.079

Note. p-values for the K-S test are presented. T-E = trauma-exposed.
*p < .05. *p < .01. ***p < .001.

An analysis of the homogeneity of variance within the data, using Levene's test, revealed that only the sleep latency data violated the assumption (see Table 3).

Table 3
Sleep-Related Variables: Results for Levene's test of homogeneity of variance

Variable	Levene's p
Sleep latency	< .001***
Sleep efficiency	.057
Number of awakenings	.450
Number of spontaneous arousals	.149
Waking minutes post sleep onset	.068
SWS percentage	.816
REM percentage	.450
REM latency	.111

***p < .001.

In summary, then, the only variables that satisfied the assumptions of parametric statistical tests were the number of spontaneous arousals, SWS percentage, and REM percentage. Of the other variables, sleep latency violated both the assumption of normality and the assumption of homogeneity of variance, whereas sleep efficiency, number of awakenings, time awake after sleep onset, and REM latency only violated the assumption of normality. Various ways to normalize the data, such as log and square-root transformations, were attempted, but because these violations occurred systematically in the data from only the PTSD and the trauma-

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exposed non-PTSD groups, transformations tended to affect the distributions of data from the depression and healthy control groups adversely. The untransformed data were therefore retained, and because (a) ANOVA is robust to violations of assumptions, and (b) most variables violated only the normality assumption, ANOVA was retained as the analysis of choice for all variables except sleep latency, the data for which were analysed using non-parametric equivalents of ANOVA.

Trends in the sleep data: Cell-mean plots. Figures 3-11 present means plots for the sleep-related variable.

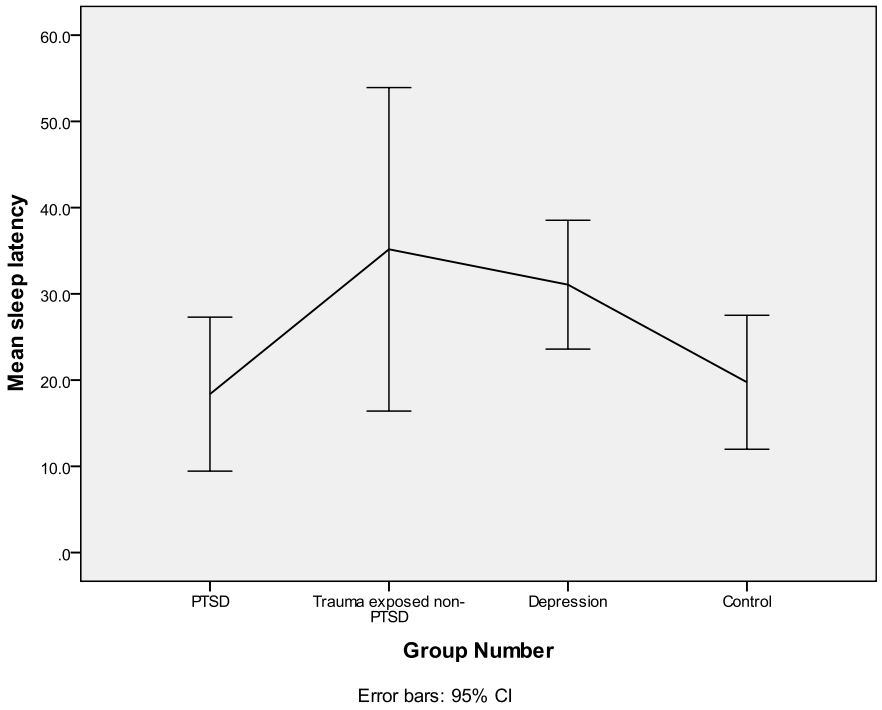

Figure 3. Sleep latency across the four groups. Error bars represent the 95% confidence interval.

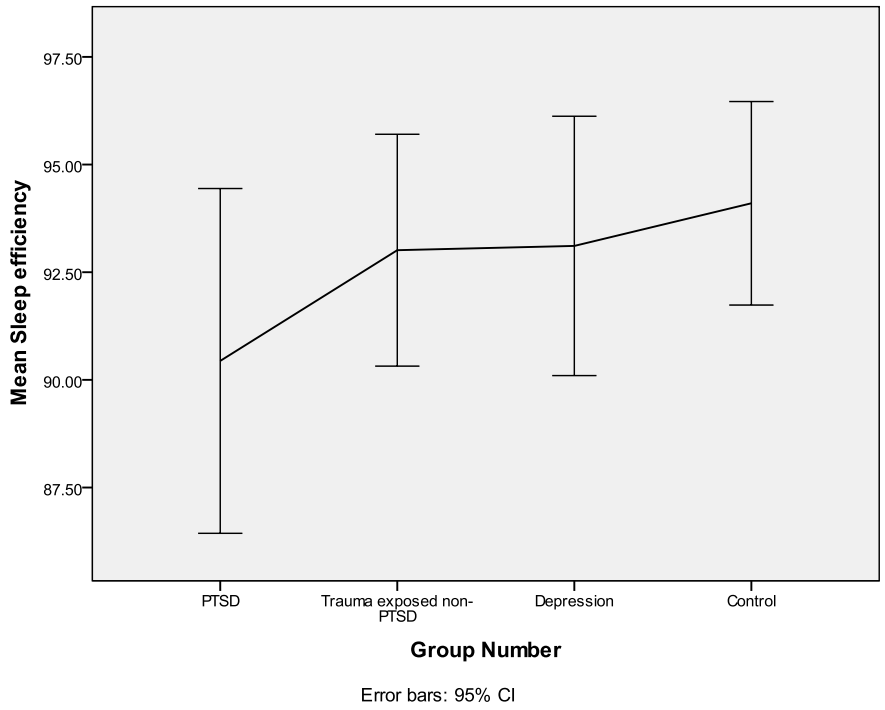

Figure 4. Sleep efficiency across the four groups. Error bars represent the 95% confidence interval.

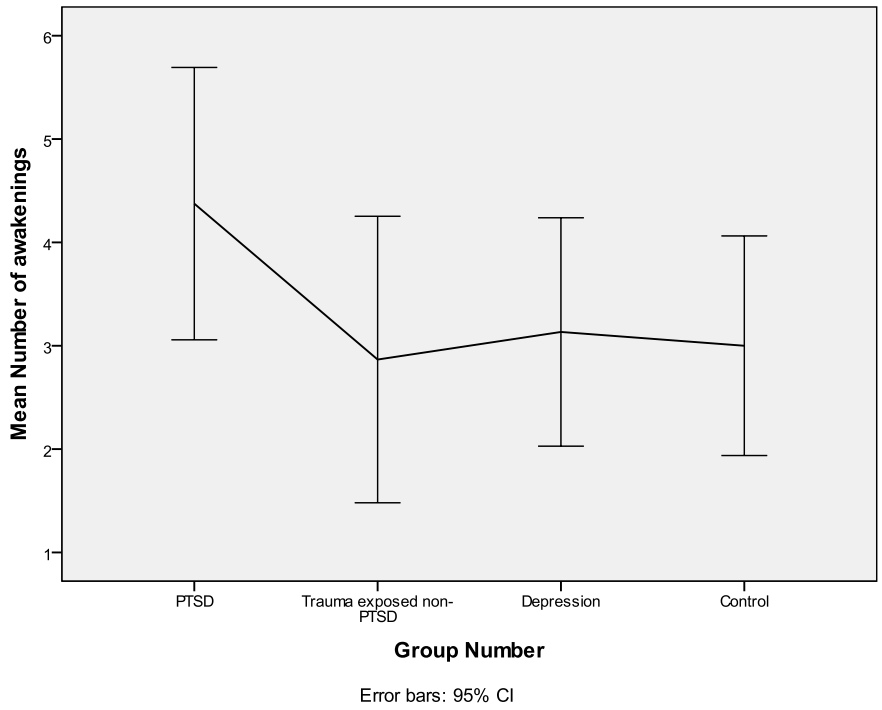

Figure 5. Number of awakenings across the four groups. Error bars represent the 95% confidence interval.

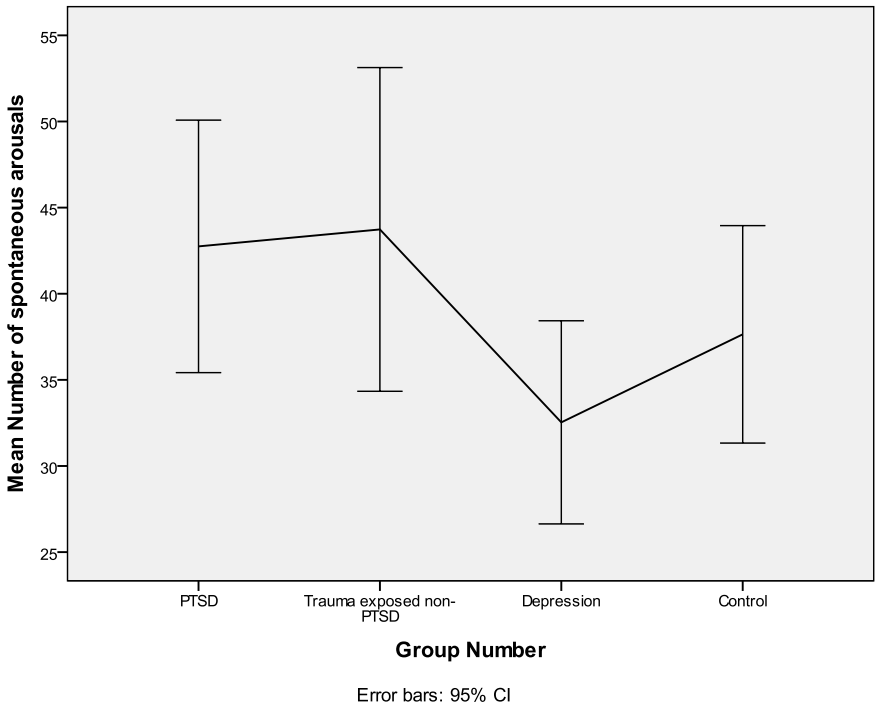

Figure 6. Number of spontaneous arousals across the four groups. Error bars represent the 95% confidence interval.

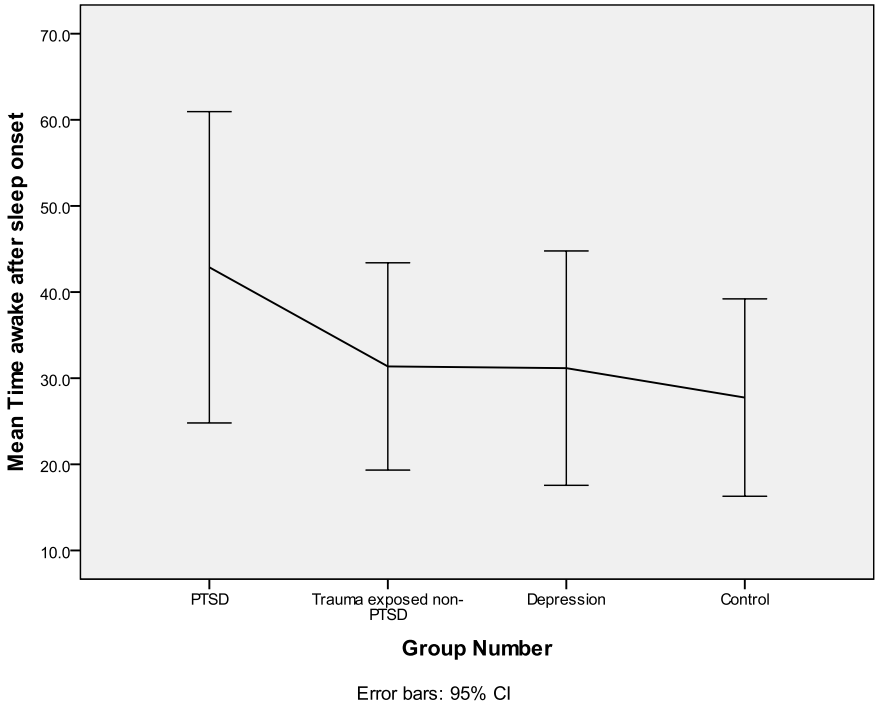

Figure 7. Time awake after sleep onset across the four groups. Error bars represent the 95% confidence interval.

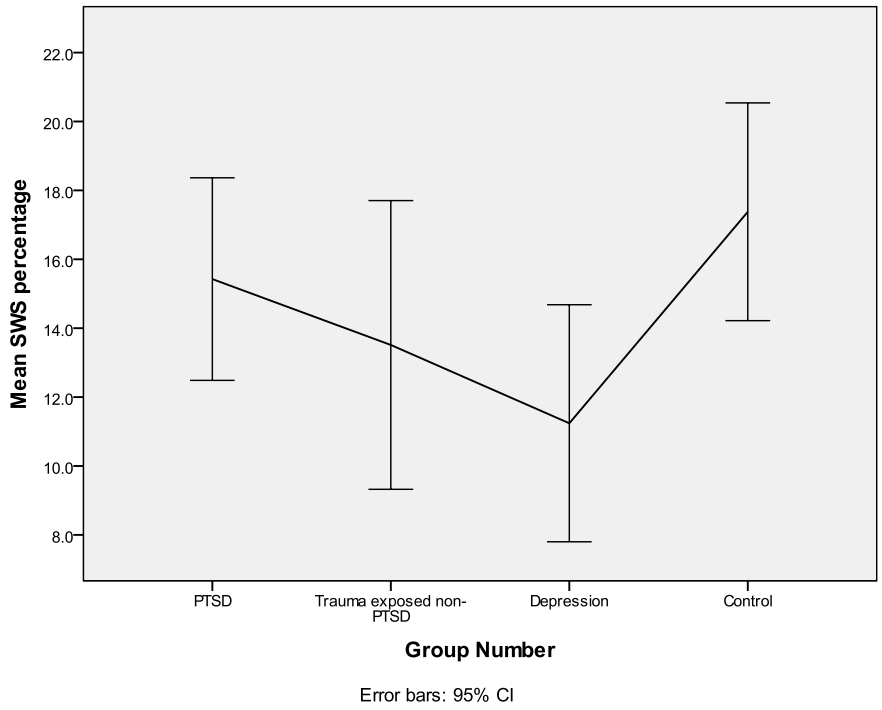

Figure 8. SWS percentage across the four groups. Error bars represent the 95% confidence interval.

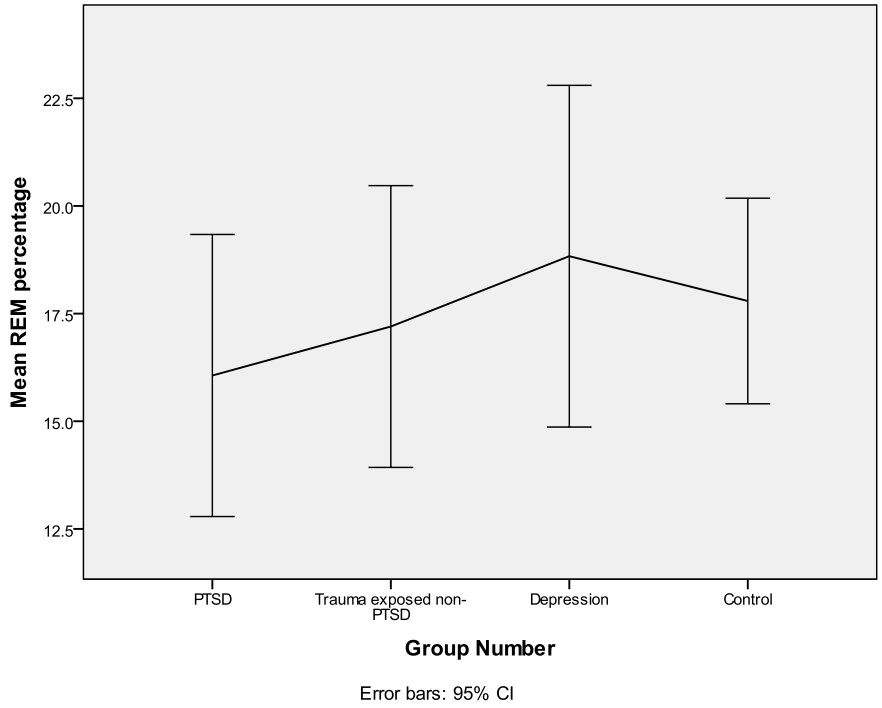

Figure 9. REM percentage across the four groups. Error bars represent the 95% confidence interval.

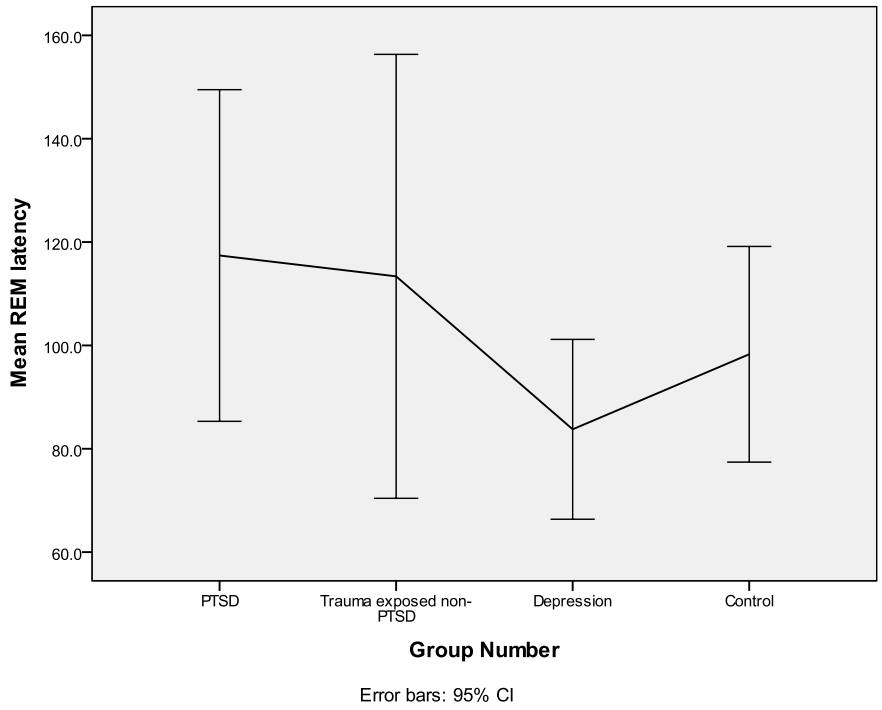

Figure 10. REM latency across the four groups. Error bars represent the 95% confidence interval.

These figures show a clear trend towards worse sleep in PTSD in five of the eight measures of sleep quality. Relative to other participants, PTSD participants spent the smallest percentage of time during the night actually sleeping, woke up the most during the night, spent the most time awake after they fell asleep, had the least REM, and took the longest time to reach their first period of REM. In terms of number of spontaneous arousals through the night, PTSD participants differed marginally from trauma-exposed non-PTSD participants; both these groups had the higher mean values than the depression and healthy control group.

In terms of sleep latency (see Figure 3), PTSD participants fell asleep the quickest; in contrast, trauma-exposed non-PTSD participants took the longest time to fall asleep. When examining this figure in conjunction with the number of awakenings (Figure 5), it is clear that although PTSD participants fell asleep the quickest, they also woke up the most. In contrast, trauma-exposed non-PTSD participants took the longest time to fall asleep and woke up the least during the night. This trend suggests an oscillation between poor and better sleep in individuals who have experienced trauma.

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In terms of SWS percentage (see Figure 8), PTSD participants had lower values than healthy controls, but not the lowest overall. Instead, depression participants had the lowest SWS percentage, followed by trauma-exposed non-PTSD individuals. Because sleep in depression is characterised by decreased SWS in comparison with healthy controls, the trend in the current data is consistent with previous research (Chokroverty, 2009a).

Furthermore, with regards to REM sleep parameters, the current trends are consistent with previous research in sleep in depression (Chokroverty, 2009a); that is to say, depressed individuals showed the highest percentage of REM and the shortest REM latency (see Figures 9 and 10).

In summary, PTSD participants showed a clear trend towards worse sleep for the majority of sleep variables. Some trends also showed support for oscillation between poor and better sleep in participants who had experienced trauma irrespective of whether they carried a PTSD diagnosis. Further, the trends supported previous findings in sleep research for depressed individuals.

Inferential statistical analyses of sleep data. A series of one-way ANOVAs set out to confirm the impressions, detailed above, garnered from the cell-mean plots of the data from the sleep-related variables. The only exception here is the sleep latency data, which were analysed using the Kruskal-Wallis test, with pairwise Mann-Whitney tests used for planned comparisons. All of these analyses sought to test the hypothesis that, in terms of these variables that characterize sleep quality, PTSD < trauma-exposed non-PTSD ? depression < healthy control (i.e., that (a) the sleep quality of PTSD participants would be worse than that of participants in all three other groups, (b) the sleep quality of healthy control participants would be better than that of participants in all other groups, and (c) the sleep quality of trauma-exposed non-PTSD participants and depression participants would fall in between the two extremes, but that (d) the relationship between the sleep quality of trauma-exposed non-PTSD and depression participants is unknown.

Table 4 shows the results of those between-group analyses. As can be seen, there were no statistically significant results, although the analyses of some variables (sleep latency, the number of spontaneous arousals, and SWS percentage) approached significance. The effect sizes estimates for each of these three variables were medium in size (Field, 2009), indicating that

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perhaps even a small increase in sample size may help to attain statistical significance and thereby show group differences. The effect size estimates for the rest of the variables were small, indicating that perhaps a much larger sample size would be needed to find statistically significant group differences.

Although initial analyses of sleep latency, number of spontaneous arousals, and SWS percentage data did not meet conventional levels of statistical significance, there were trends toward significance, and between-group differences were associated with medium effect sizes. Hence, further analyses of those data, in an attempt to clarify the nature of the relationship between groups on those variables, were justified. Because the a priori prediction was that, for each of the three variables, PTSD < trauma-exposed non-PTSD ? depressed < healthy control, a set of orthogonal planned comparisons (the same set for each variable) were conducted on the two sets of data (number of spontaneous arousals and SWS percentage) that had been analyzed using ANOVA initially (these comparisons are outlined in the statistical analysis section).

Because data from the sleep latency variable had been analyzed initially using the non-parametric Kruskal-Wallis test, as a follow-up three pairwise Mann-Whitney tests were conducted, with a Bonferroni adjustment leading to a critical value of $p = 0.017$. The three pairwise tests matched the order of the set of orthogonal comparisons outlined in the statistical analysis section, and the logic behind the analysis is identical to that explained in the afore mentioned section. That is for the first comparison the healthy control group was compared to the data of the PTSD, trauma-exposed non-PTSD and depression groups together while for the second comparison the PTSD group was compared to the data of the trauma-exposed non-PTSD and depression groups together. For the third comparison the trauma-exposed non-PTSD group was compared to the depression group.

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Table 4
Sleep-Related Variables: Descriptive statistics and results from between-group comparisons

	Group						
Variable	PTSD (n = 16)	T-E non-PTSD (n = 15)	Depression (n = 15)	Healthy Control (n = 14)	*F/H*	*p*	ESE
Sleep latency	18.38 (16.76)	35.87 (33.87)	31.07 (13.49)	19.75 (13.45)	7.68[a]	.053	.33
Sleep efficiency	90.44 (7.51)	93.01 (4.86)	93.11 (5.44)	94.10 (4.09)	1.16	.332	.24
Number of awakenings	4.38 (2.47)	2.87 (2.50)	3.13 (2.00)	3.00 (1.84)	1.52	.220	.27
Number of spontaneous arousals	42.75 (13.76)	43.73 (16.97)	32.53 (10.65)	37.64 (10.93)	2.28	.092	.33
Waking minutes after sleep onset	42.88 (33.92)	31.38 (21.73)	31.17 (24.57)	27.75 (19.84)	1.01	.397	.23
SWS percentage	15.43 (5.51)	13.51 (7.57)	11.24 (6.21)	17.38 (5.47)	2.58	.063	.35
REM percentage	16.06 (6.15)	17.20 (5.91)	18.83 (7.16)	17.79 (4.13)	0.58	.630	.17
REM latency	117.40 (57.95)	113.37 (77.57)	83.77 (31.42)	98.29 (36.14)	1.20	.320	.25

Note. Means are presented with standard deviations in parentheses. Degrees of freedom in each case were (3, 56), except for sleep latency, where the degrees of freedom for the Kruskal-Wallis test were 3. T-E = trauma-exposed. ESE = effect size estimate (in this case, *r*).
[a] H statistic reported.

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Table 5 shows the results of the set of orthogonal comparisons for the data from each of the sleep latency, number of spontaneous arousals, and SWS percentage measures. With regard to sleep latency, only the results of the second comparison were statistically significant, with the overall pattern of results suggesting that (a) contrary to the a priori prediction, mean sleep latency was not shorter in the healthy control group than in the other three groups, (b) contrary to the a priori prediction that PTSD participants would take the longest time to fall asleep, mean sleep latency in the PTSD group (*Mdn* = 13.5) was shorter than that in the trauma-exposed non-PTSD and depression groups (*Mdn* = 25.75), and (c) there were no statistically significant differences for sleep latency between the trauma-exposed non-PTSD and depression group.

In summary, this analysis did not confirm the prediction that, with regard to sleep latency, PTSD < trauma-exposed non-PTSD ? depressed < healthy control (with a longer sleep latency indicating disordered sleep). In fact, participants in the PTSD group tended to fall asleep more quickly than their counterparts in the trauma-exposed non-PTSD and depression groups. Although the effect sizes for comparison 1 and 3 were small, the effect size for comparison 2 was medium suggesting that a shorter sleep latency period in PTSD participants in comparison with trauma-exposed non-PTSD and depressed participants is reflective of the population.

With regard to the number of spontaneous arousals, only the results of the third comparison were statistically significant, with the overall pattern of results suggesting that (a) contrary to the a priori prediction, participants in the healthy control group did not have significantly fewer spontaneous arousals than those in the other groups, (b) contrary to the a priori prediction, participants in the PTSD group did not have significantly fewer spontaneous arousals than those in the trauma-exposed non-PTSD and depression groups, and (c) contrary to the a priori prediction, participants in the trauma-exposed non-PTSD group had significantly more spontaneous arousals (*M* = 43.73, *SD* = 16.97) than those in the depression group (*M* = 32.53, *SD* = 10.65).

Although these findings with regard to the number of spontaneous arousals disconfirm the set of a priori predictions, they are consistent with the trend indicated by the cell mean plot for these data (see Figure 6): participants in the PTSD and trauma-exposed non-PTSD groups tend to have more frequent spontaneous arousals than those in the depression and healthy control groups, and the number of awakenings for the PTSD and trauma-exposed non-PTSD groups is

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very similar. There was not enough power in the current study to detect statistically significance in these trends, however, and once again the effect sizes associated with each comparison were small.

With regard to SWS percentage, only the results of the first comparison were statistically significant, with the overall pattern of results suggesting that (a) consistent with the a priori prediction, participants in the healthy control group had significantly more SWS percentage (M = 17.38, SD = 5.47) than those in the other three groups taken together (M = 13.44, SD = 6.43), (b) contrary to the a priori prediction, participants in the PTSD group did not have a significantly different amount of SWS than those in the trauma-exposed non-PTSD and depression groups, and (c) consistent with the a priori prediction, participants in the trauma-exposed non-PTSD and depression groups had a similar percentage of SWS.

Although the effect sizes associated with this set of comparisons were in the range conventionally described as small (Field, 2009), SWS percentage shows promise in satisfying the set of predictions PTSD < trauma-exposed non-PTSD ? depressed < healthy control, and hence may have potential as a marker of disordered sleep in PTSD.

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Table 5
Sleep-Related Variables: Results from orthogonal comparisons on three variables of interest

Variable / Contrast number	*t* / *U*	*p*	*ESE*
Sleep latency			
Contrast #1	274.00	.204	.11
Contrast #2	136.00	< .001***	.35
Contrast #3	93.00	.256	.15
Number of spontaneous arousals			
Contrast #1	0.50	.621	.07
Contrast #2	1.15	.269	.15
Contrast #3	2.29	< .05*	.29
SWS percentage			
Contrast #1	-2.09	< .05*	.27
Contrast #2	1.58	.121	.21
Contrast #3	1.00	.324	.13

Note. Contrast #1 = (PTSD, trauma-exposed non-PTSD, depression) versus healthy control. Contrast #2 = (trauma-exposed non-PTSD, depression) versus PTSD. Contrast #3 = trauma-exposed non-PTSD versus depression. Degrees of freedom in each case were 56, except for sleep latency which was analysed using the Mann-Whitney *U*-test. ESE = effect size estimate (in this case, *r*).
*p < .05. **p < .01. ***p < .001.

Subjective ratings of sleep quality. To get an indication of how participants thought they slept in the lab, values where allocated for four questions – '*Did you sleep worse, normal or better*?', '*Did the equipment bother you?*', '*How many times did you wake up during the night*?' and how long they thought it took them to fall asleep. Answers to the first question were assessed on the scale *better* = 2, *normal* = 1, and *worse* = 0. Answers to the second question were coded *yes* = 1 and *no* = 0. For the third question, the number of awakenings reported by the participant served as the score. For the fourth question, I asked participants, from the time I turned off the lights, how long in minutes had it taken them to fall asleep. This answer was used as the score for subjective sleep latency.

One-way ANOVA was conducted on subjective sleep quality, the number of subjective awakenings and subjective sleep latency. These tests met the assumption of homogeneity of variance, but broke the assumption of normality. However ANOVA was utilised as it is robust to violations of assumptions (Field, 2009). Chi-squared analysis was performed on subjective experience of the sleep equipment (as responses fell into a category '*yes'* or '*no'*).

Figure 11 shows group mean data for the first question. Participants in the PTSD group rated their sleep best, followed by participants in the trauma-exposed non-PTSD and depression groups. Healthy control participants rated their sleep quality the worst relative to the other groups. A one-way ANOVA conducted on these data showed trends toward statistical significance (see Table 6).

What is striking about these self-report data is that objective measures indicate a trend towards *worse* sleep in the PTSD group; however, the subjective measures described and analysed above suggest that the PTSD group slept *better* in comparison with other groups. The vast majority of previously published studies in this area (see, e.g., Neylan, et al., 1998; Ohayon & Shapiro, 2000) is consistent with the current objective data, however: individuals diagnosed with PTSD tend to rate their sleep as worse than objective measures suggest it is.

One way to explain the current pattern of data emerges from participants' answers to the follow-up question of why they slept how they did. The most common answer for participants from the PTSD and trauma-exposed non-PTSD groups was that they felt safe. This subjective perception may be supported tentatively by the objective measure of sleep latency, which indicated that participants in the PTSD group fell asleep the quickest, even though overall

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objective measures point to worse sleep in that group. The subject reports of better sleep observed in the PTSD group may be a local phenomenon: the laboratory environment was safer than the home environment for most, if not all, of the participants, and this difference is particularly salient for those individuals with previous experiences of trauma. If individuals in the PTSD group did indeed sleep better than they usually would in their home environment, the objective measures for individuals in this group may be moderated by the environment in which the experiment took place – that is objective measures of sleep latency, sleep efficiency etc may have presented better in the sleep laboratory than they usually would in participants' home environments.

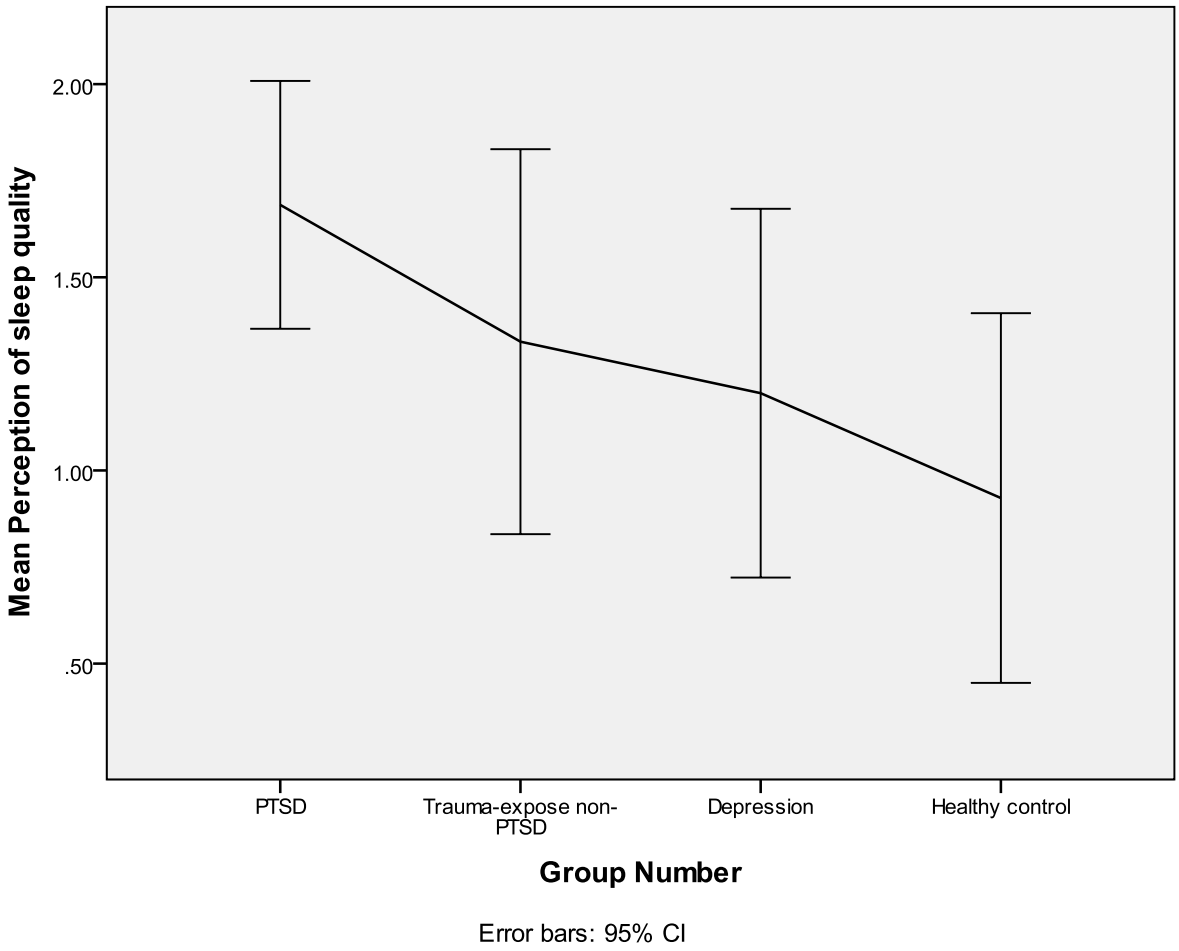

Figure 11. Subjective ratings of sleep quality across the four groups. Error bars represent 95% confidence intervals.

Table 6
Subjective Reports of Sleep Quality: ANOVA results

Variable	*M*	*SD*	*F*/χ^2	*p*	ESE
Perceived sleep quality	1.30	0.83	2.33	.084	.33
Sleep lab equipment			0.51[a]	.915	.09
Perceived awakenings	1.53	1.41	0.43	.732	.15
Perceived sleep latency	43.09	31.39	1.75	.171	.33

Note. Degrees of freedom in each case were (3, 56), except for sleep latency where they were (3, 43) because 14 participants did not answer the question and sleep lab equipment where the degrees of freedom for the chi-squared test were 3. ESE = effect size estimate (in this case, *r* except for sleep lab equipment where Cramer's V is used).
[a] χ^2 statistic reported

With regard to the second question, about how participants perceived the sleep lab equipment, a one-way ANOVA did not detect statistically significant between-group differences (see Table 6). Hence, it appears that, across groups, participants rated the experience of sleeping with sleep lab equipment equally. This report is reassuring because it means that any group differences in sleep quality cannot be ascribed to group differences in the subjective experience of sleeping with electrodes.

With regard to the third question, about the number of times participants remembered waking up during the night, a one-way ANOVA did not detect statistically significant between-group differences (see Table 6). This pattern of data is consistent with the objective measure of number of awakenings.

With regard to the fourth question, about how long participants thought it took to fall asleep, a one-way ANOVA did not detect any statistically significant between-group differences (see Table 6). That is participants in each of the four groups did not perceive the time it took them to fall asleep any differently from each other.

Interim summary: Between-group differences in sleep quality. Overall, Hypothesis 1, which stated that (a) sleep quality in PTSD participants would be worse than that in all of the other participants, and that (b) sleep quality in trauma-exposed non-PTSD and depression participants would be worse than that in healthy controls, was not confirmed: group differences in sleep variables were not statistically significant. However, data from the measures of sleep latency, the number of spontaneous arousals, and SWS percentage approached conventional

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levels of statistical significance, and between-group comparisons on those variables were associated with medium effect sizes, suggesting that a larger sample may attain statistical significance and thereby show group differences. Planned pairwise comparisons on the data from these measures showed mixed results in supporting Hypothesis 1, however, with the number of spontaneous arousals and SWS percentage showing the most promising results.

There were no statistically significant between-group differences, and no trends toward such significance, for the variables sleep efficiency, number of awakenings, time awake after sleep onset, REM percentage, and REM latency. Furthermore, the effect sizes associated with the overall group comparisons were small in each of these cases, indicating that a much larger sample would be needed to detect statistical significance (and, of course, with a much larger sample one runs the risk of making small differences that have no *clinical* significance, statistically significant).

Subjective reports on the quality of sleep at the sleep laboratory suggested that PTSD and trauma-exposed non-PTSD participants slept better than healthy controls. This finding is in juxtaposition with objective measures which show a tendency to worse sleep in PTSD and trauma-exposed non-PTSD participants and may be explained by participants' subjective experiences of the sleep environment. Thus the sleep laboratory environment may have moderated sleep parameters for PTSD and trauma-exposed non-PTSD individuals – that is at home these individuals may sleep worse than in the laboratory.

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Testing Hypotheses 2 and 3: Between-group memory differences

The outcome measures for memory performance were derived from three declarative memory tasks (the verbal paired-associates (VPA) test, the WMS-III Logical Memory subtest (LM) and the Autobiographical Memory Test (AMT)), and from a procedural memory task (the Walker et al. (2003) Finger Tapping Task (FTT)). Apart from the AMT, each of these instruments was administered in the evening and in the morning. Hence, performance on each of these can be characterised by an encoding score (derived from the evening administration), a delayed recall score (derived from the morning administration), and a percentage retention score (derived from an evaluation of the morning score taking into account the evening (baseline)

score). In contrast the AMT draws on memories of participants' past experiences and can be seen as an autobiographical memory recall task[6].

Hypothesis 2 focused on between-group differences in encoding and delayed recall. The set of a priori predictions was that (a) participants who have experienced trauma will, regardless of whether they are carrying a PTSD diagnosis or not, perform more poorly than healthy controls on declarative memory tasks, (b) participants with a PTSD diagnosis will perform more poorly than those in the other groups on declarative memory tasks, (c) healthy controls will show the best performance on declarative memory tasks, and (d) there will be no between-group differences on measures of procedural memory. There were no specific predictions with regard to the relative performance of the depression group, for reasons outlined earlier.

Hypothesis 3 focused on between-group differences in percent retention after a period of sleep. The set of a priori predictions here was that that (a) participants who have experienced trauma will, regardless of whether they are carrying a PTSD diagnosis or not, perform more poorly than healthy controls in terms of retention of declarative memory information, (b) participants with a PTSD diagnosis will perform more poorly than those in the other groups in terms of retention of declarative memory information, (c) healthy controls will show the best performance in terms of retention of declarative memory information, and (d) there will be no between-group differences on measures of procedural memory retention. There were no specific predictions with regard to the relative performance of the depression group, for reasons outlined earlier.

These predictions were tested using one-way ANOVA. Although there is an argument for using repeated-measures ANOVA on the evening (before sleep) and morning (after sleep) scores to characterise an interaction between performance before and after sleep, this approach was not followed for two reasons. First, the percent retention scores already characterise group differences between baseline (pre-sleep) and post-sleep scores. Second, an interaction between pre- and post-sleep scores will explain whether sleep had an impact on memory as a whole (aside from group differences). However, this study was not designed to answer that question; if it had been, I would have included a control for the sleep intervention (e.g., a group that stayed awake

[6] Autobiographical memory is a kind of episodic memory – memory that has a time dimension (one can remember *when* a particular thing happened) in contrast to facts which have no time dimension – for e.g. the Eiffel Tower is in Italy but one might not know when one learnt this. Episodic memory falls under declarative memory.

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all night to control for the effect of sleep, or a group that took the memory tests in the morning and then again in the evening, with only wakefulness in-between). Otherwise stated, for the purposes of this study, and the questions this study was designed to answer, the interaction results would not provide any useful information, and therefore repeated-measures ANOVA was not the appropriate analytic strategy.

Significant ANOVA results were analysed using planned comparisons that tested the hypothesis PTSD < trauma-exposed ? depressed < healthy control. The same sets of contrasts were used as for the sleep data and as outlined in the statistical analysis section.

Memory data: Testing assumptions. Before the data were analysed, the assumptions underlying parametric statistical analysis (viz., normality of distribution and homogeneity of variance) were tested for all 10 memory outcome measures: VPA pre-sleep immediate recall (VPA-EVE), VPA post-sleep delayed recall (VPA-MORN), VPA percent retention across the sleep-delay interval (VPA%), LM pre-sleep immediate recall (LM-EVE), LM post-sleep delayed recall (LM-MORN), LM percent retention across the sleep-delay interval (LM%), FTT pre-sleep immediate recall (FTT-EVE), FTT post-sleep delayed recall (FTT-MORN), FTT percent retention across the delay interval (FTT%), and AMT total score.

An analysis of normality of data distribution using the Kolmogorov-Smirnov test revealed that the data for 5 of the 10 outcome measures (LM-EVE, LM%, FTP-EVE, FTP-MORN, and AMT total) were normally distributed; the other distributions violated normality. Again, as for the sleep data, the data within each group for each outcome measure were assessed for normality. The results of those analyses are shown in Table 7.

Unlike the case with some of the sleep-related variables, with regard to the memory data there was no expectation that scores would cluster around a particular value; rather, one would expect scores to be distributed normally. The violations of normality are therefore probably due to the small sample sizes in each group.

An analysis of the homogeneity of variance within the data, using Levene's test, revealed that none of the tests violated this assumption (see Table 8).

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Table 7
Memory Variables: Results for the Kolmogorov-Smirnov test of normality

	Group			
Test / Outcome measure	PTSD (*n* = 16)	T-E non-PTSD (*n* = 15)	Depression (*n* = 15)	Healthy control (*n* = 14)
VPA				
Immediate recall	0.200	0.200	0.009**	0.200
Delayed recall	0.022	0.200	0.012*	0.106
Percent retention	0.104	0.098	0.078	< .001***
LM				
Immediate recall	0.200	0.200	0.186	0.122
Delayed recall	0.200	0.200	0.018*	0.080
Percent retention	0.200	0.200	0.200	0.064
FTT				
Immediate recall	0.200	0.200	0.200	0.200
Delayed recall	0.200	0.200	0.200	0.200
Percent retention	0.200	0.002**	0.003**	0.200
AMT total	0.736	0.409	0.987	0.981

Note. p-values for the K-S test are presented. T-E = trauma-exposed. VPA = verbal paired-associates test; LM = WMS-III Logical Memory test; FTT = Finger Tapping Task. AMT = Autobiographical Memory Test. Immediate recall measures are those taken in the evening, pre-sleep; delayed recall measures are those taken in the morning, post-sleep; percent retention measures are those based on the percentage of the material remembered in the evening that was also remembered in the morning.
*$p < .05$. **$p < .01$. ***$p < .001$.

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Table 8
Memory Variables: Results for Levene's test of homogeneity of variance

Test / Outcome measure	Levene's *p*
VPA	
Immediate recall	0.754
Delayed recall	0.772
Percent retention	0.271
LM	
Immediate recall	0.657
Delayed recall	0.706
Percent retention	0.177
FTT	
Immediate recall	0.434
Delayed recall	0.574
Percent retention	0.856
AMT total	0.602

Note. VPA = verbal paired-associates test; LM = WMS-III Logical Memory test; FTT = Finger Tapping Task. AMT = Autobiographical Memory Test. Immediate recall measures are those taken in the evening, pre-sleep; delayed recall measures are those taken in the morning, post-sleep; percent retention measures are those based on the percentage of the material remembered in the evening that was also remembered in the morning.

Because ANOVA is robust to violations of its assumptions, and because only the assumption of normality was violated for some of the tests, this statistical method was retained as the analysis of choice for all memory outcomes measures.

Trends in the VPA data: Cell-mean plots. Figures 12-14 present cell-mean plots for the three VPA outcome measures.

The VPA-EVE and VPA-MORN cell-mean plots (Figures 12 and 13) show that, on average and contrary to expectations, participants in the PTSD group performed best on these measures. In contrast, the depression group performed worst. The VPA% cell-mean plot (Figure 14), however, shows an inverse relationship; that is, after encoding and a period of sleep, participants in the depression group remembered more of what they had encoded than did participants in the other groups. In terms of percent retention, the trauma-exposed non-PTSD group performed the worst.

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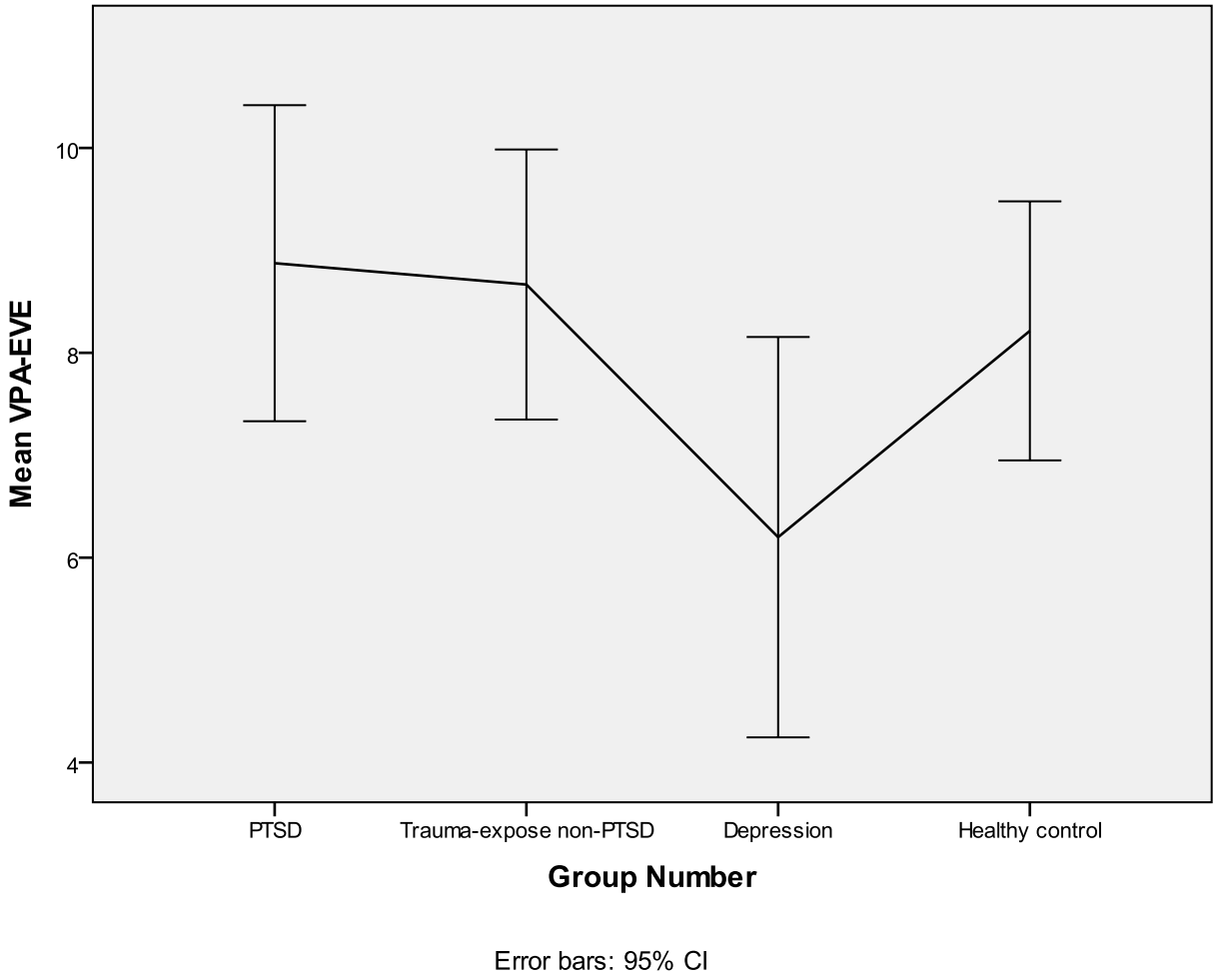

Figure 12. Group mean data for verbal paired-associates task pre-sleep immediate recall. Error bars represent the 95% confidence interval.

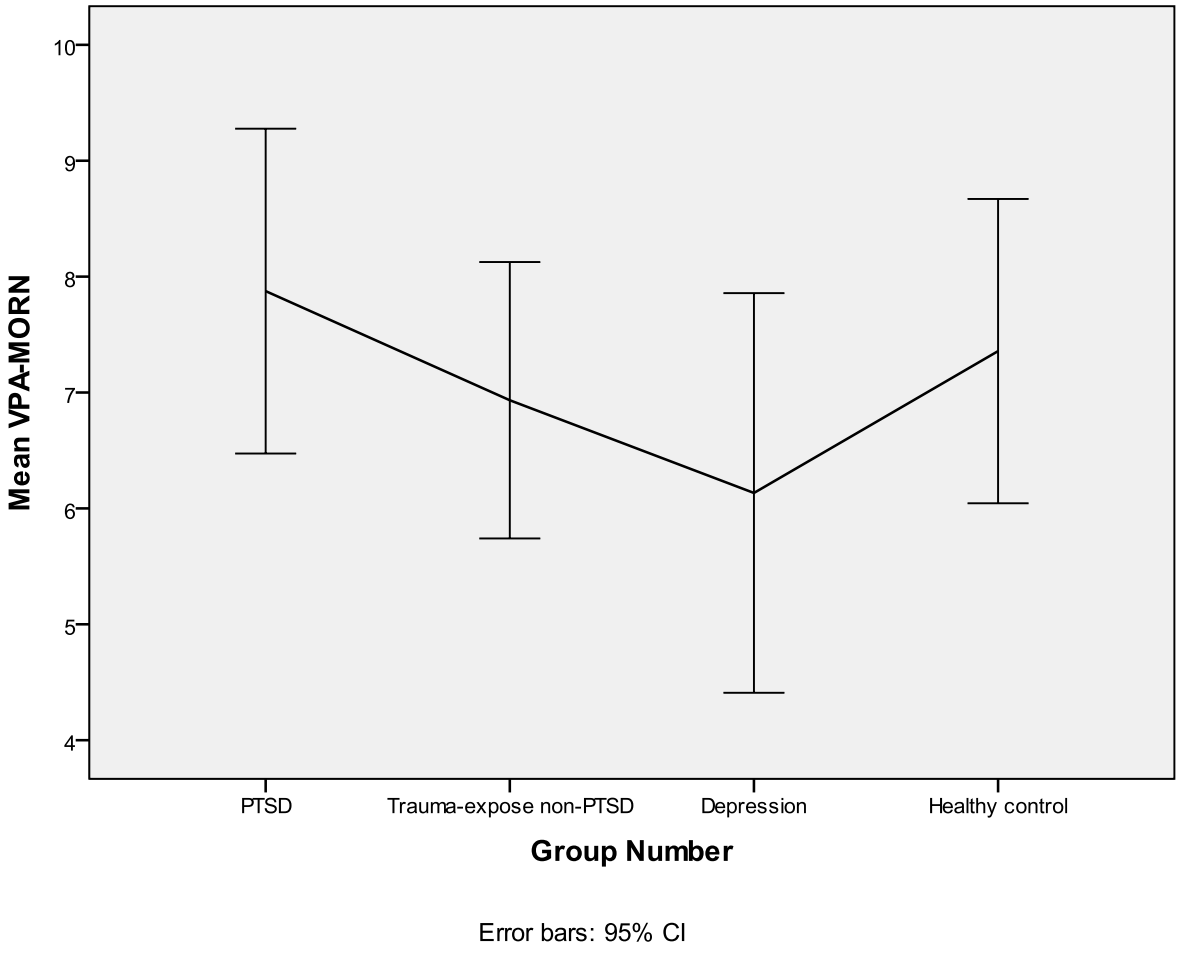

Figure 13. Group mean data for verbal paired-associates task post-sleep delayed recall. Error bars represent the 95% confidence interval.

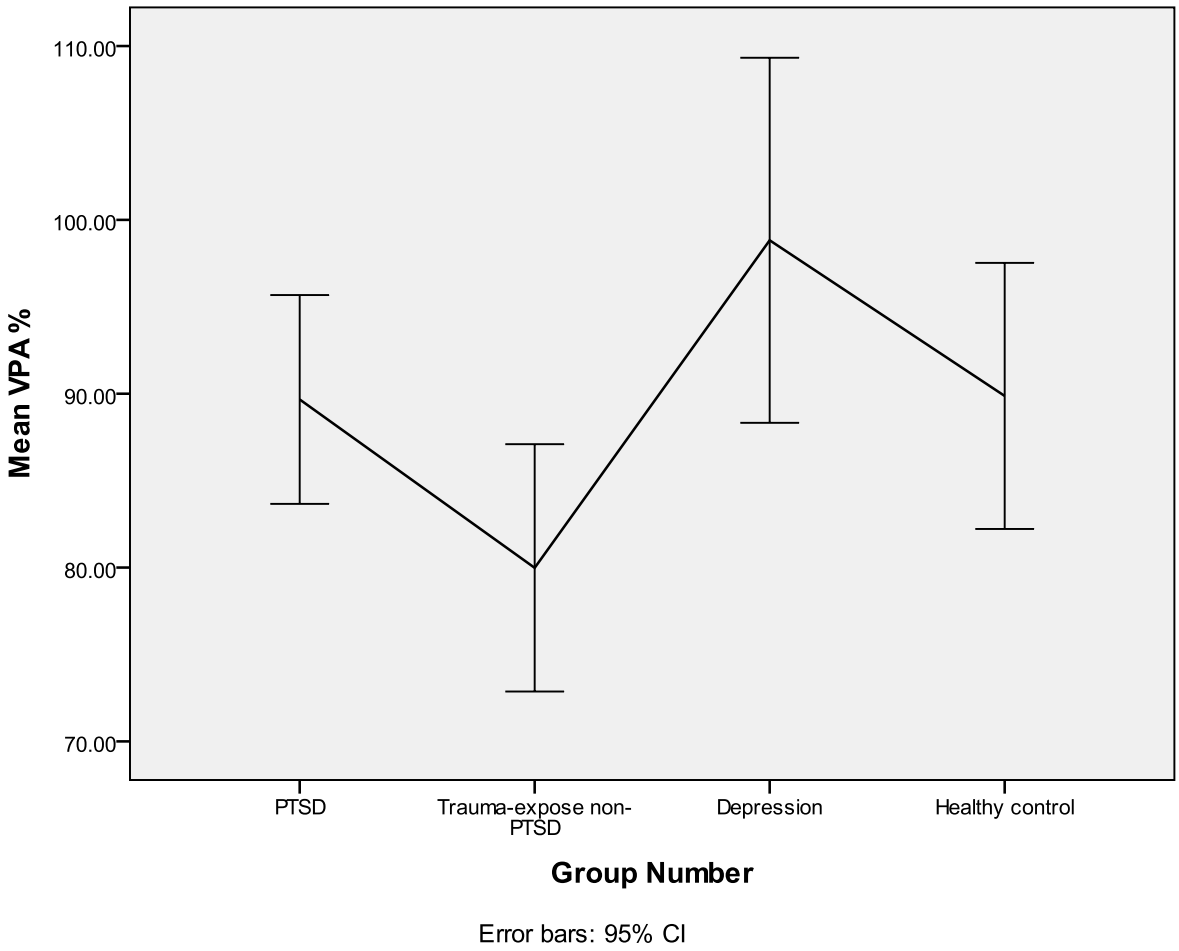

Figure 14. Group mean data for verbal paired-associates task percent retention. Error bars represent the 95% confidence interval.

Inferential statistical analyses of VPA data. Table 9 shows the results of a series of one-way ANOVAs conducted on the three VPA outcome measures. There were statistically significant between-group differences with regard to VPA-EVE (immediate recall) and VPA percent retention, and these were associated with medium effect sizes. There were, however, no statistically significant between-group differences with regard to VPA-MORN (delayed recall), although the effect size here was not insubstantial.

The set of orthogonal planned comparisons outlined earlier were conducted on the data from the two outcome variables that delivered statistically significant ANOVA results. The results from those planned comparisons are shown in Table 10. The first and second contrasts showed, respectively, that healthy controls performed similarly to the other three groups taken together, and that the PTSD group performed similarly to the trauma-exposed and depression groups taken together, in terms of both VPA-EVE and VPA%. The third contrast for the VPA-EVE data showed that the trauma-exposed non-PTSD group performed significantly better than the depression group, whereas the same contrast for the VPA% data showed significant results in the opposite direction.

Overall, then, inferential statistical analysis of the VPA data did not confirm the set of a priori predictions with regard to declarative memory performance (both in terms of encoding, recall and retention) that might be summarized as PTSD < trauma-exposed ? depressed < healthy control. The only statistically significant between-group differences were on immediate recall, where participants in the depression group performed more poorly than those in the trauma-exposed non-PTSD group, and on percent retention, where participants in the trauma-exposed non-PTSD group performed more poorly than those in the depression group. The meaning of these results is unclear - there were no a priori predictions relating to the performance of these two groups relative to one another, and this set of results does not lend itself to easy interpretation. More studies need to be done to clarify their standing relative to one another with regard to memory performance.

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Table 9
Memory Performance: Descriptive statistics and results from between-group comparisons

	Group						
Variable	PTSD (n = 16)	T-E non-PTSD (n = 15)	Depression (n = 15)	Healthy Control (n = 14)[a]	F	p	ESE
VPA							
Immediate recall	8.88 (2.90)	8.67 (2.38)	6.20 (3.53)	8.21 (2.19)	2.88	.044*	.37
Delayed recall	7.88 (2.63)	6.93 (2.15)	6.13 (3.11)	7.36 (2.27)	1.25	.299	.25
Percent retention	89.67 (11.27)	79.98 (12.85)	98.83 (18.96)	89.87 (13.26)	4.31	.008**	.43
LM							
Immediate recall	6.94 (2.70)	5.40 (2.80)	6.00 (2.59)	7.64 (3.13)	1.84	.151	0.30
Delayed recall	7.56 (2.90)	6.13 (2.23)	7.60 (2.10)	9.29 (2.27)	4.15	.010*	0.43
Percent retention	8.19 (3.21)	8.87 (2.90)	11.21 (2.08)	9.87 (1.96)	3.75	.016*	0.41
FTT							
Immediate recall	11.85 (3.15)	9.44 (3.18)	9.81 (3.65)	10.02 (2.63)	1.78	.161	.30
Delayed recall	13.48 (4.76)	10.40 (4.43)	11.73 (3.72)	11.79 (3.75)	1.36	.265	.26
Percent retention	112.25 (33.08)	109.54 (43.37)	126.54 (35.13)	117.08 (22.22)	0.69	.564	.20
AMT total	14.00 (5.91)	12.33 (6.91)	17.53 (7.01)	19.53 (5.32)	3.66	.018	.41

Note. Means are presented with standard deviations in parentheses. Degrees of freedom in each case were (3, 56), except for the AMT analyses, where they were (3, 55). T-E = trauma-exposed. ESE = effect size estimate (in this case, r). VPA = verbal paired-associates test; LM = WMS-III Logical Memory test; FTT = Finger Tapping Task. AMT = Autobiographical Memory Test. Immediate recall measures are those taken in the evening, pre-sleep; delayed recall measures are those taken in the morning, post-sleep; percent retention measures are those based on the percentage of the material remembered in the evening that was also remembered in the morning.
[a]n = 13 for the analyses of AMT data.
*p < .05. **p < .01.

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Table 10
Memory Performance: Results from orthogonal comparisons on five variables of interest

Variable / Contrast number	*t*	*p*	*ESE*
VPA immediate recall			
Contrast #1	-0.35	.727	.05
Contrast #2	1.66	.103	.22
Contrast #3	2.41	.020*	.31
VPA percent retention			
Contrast #1	-0.09	.931	.01
Contrast #2	0.60	.953	.01
Contrast #3	-3.60	.004**	.43
LM delayed recall			
Contrast #1	-2.98	.004**	.37
Contrast #2	-0.93	.354	.12
Contrast #3	-1.67	.101	.22
LM percent retention			
Contrast #1	-2.81	.007**	.35
Contrast #2	-1.46	.150	.19
Contrast #3	-1.05	.299	.14
AMT total			
Contrast #1	-2.37	.020*	.31
Contrast #2	-0.48	.637	.06
Contrast #3	-2.24	.029*	.29

Note. Contrast #1 = (PTSD, trauma-exposed non-PTSD, depression) versus healthy control. Contrast #2 = (trauma-exposed non-PTSD, depression) versus PTSD. Contrast #3 = trauma-exposed non-PTSD versus depression. Degrees of freedom in each case were 56, except for the AMT analyses, where they were 55. ESE = effect size estimate (in this case, *r*). VPA = verbal paired-associates test; LM = WMS-III Logical Memory test; FTT = Finger Tapping Task. AMT = Autobiographical Memory Test. Immediate recall measures are those taken in the evening, pre-sleep; delayed recall measures are those taken in the morning, post-sleep; percent retention measures are those based on the percentage of the material remembered in the evening that was also remembered in the morning.
*$p < .05$. **$p < .01$.

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Trends in the LM data: Cell-mean plots. Figures 15-17 present cell-mean plots for the three LM outcome measures. The LM-EVE and LM-MORN cell-mean plots (Figures 15 and 16) show that, on average and consistent with a priori predictions, the healthy control group performed the best. Contrary to predictions, however, the trauma-exposed non-PTSD group performed the worst both before and after sleep. The LM% cell-mean plot (Figure 17), however, shows that, on average, participants in the PTSD group retained the least amount of information after a period of sleep in comparison to what they encoded, closely followed by the trauma-exposed group and then the depression group, with participants in the healthy control group retaining the most information. This trend is consistent with the a priori prediction PTSD < trauma-exposed non-PTSD ? depression < healthy control.

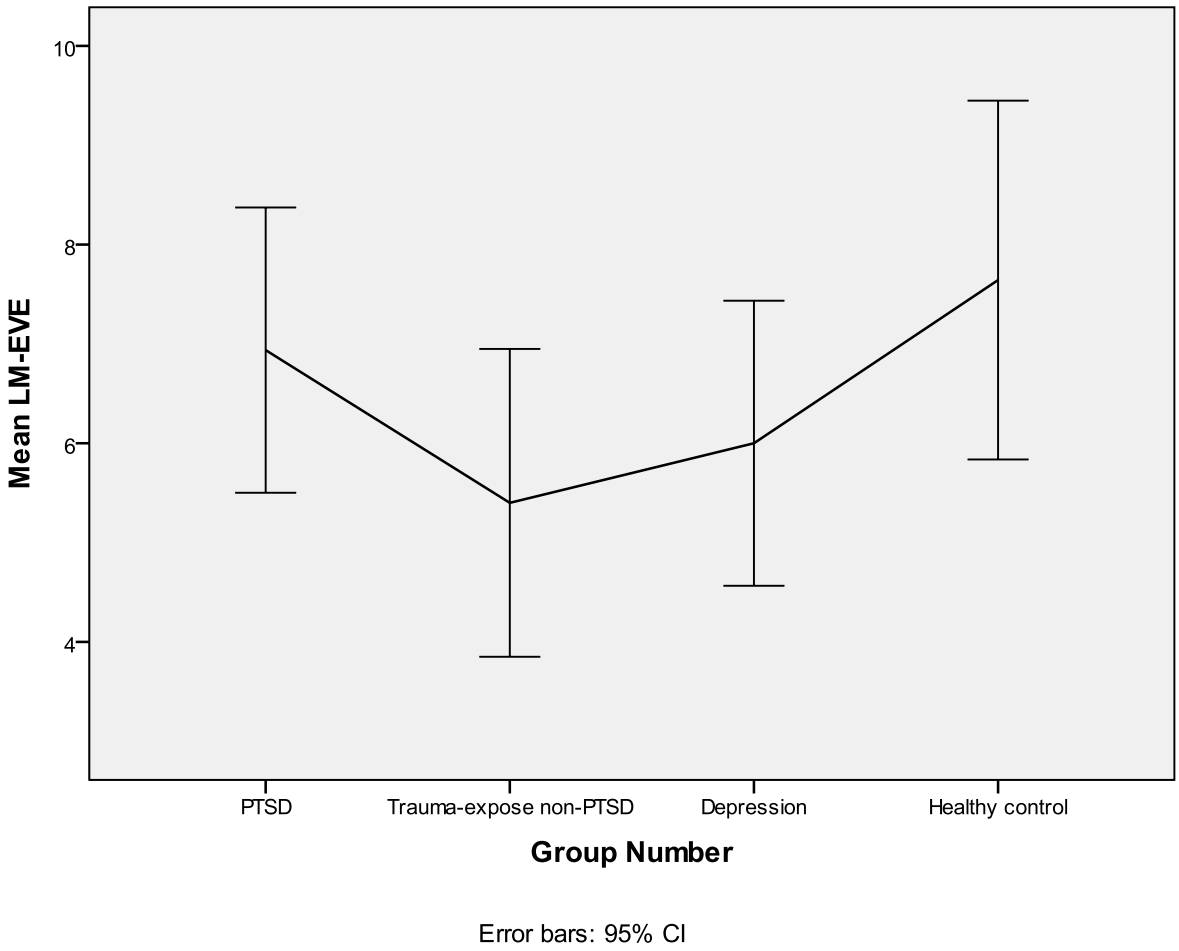

Figure 15. Group mean data for WMS-III Logical Memory pre-sleep immediate recall. Error bars represent the 95% confidence interval.

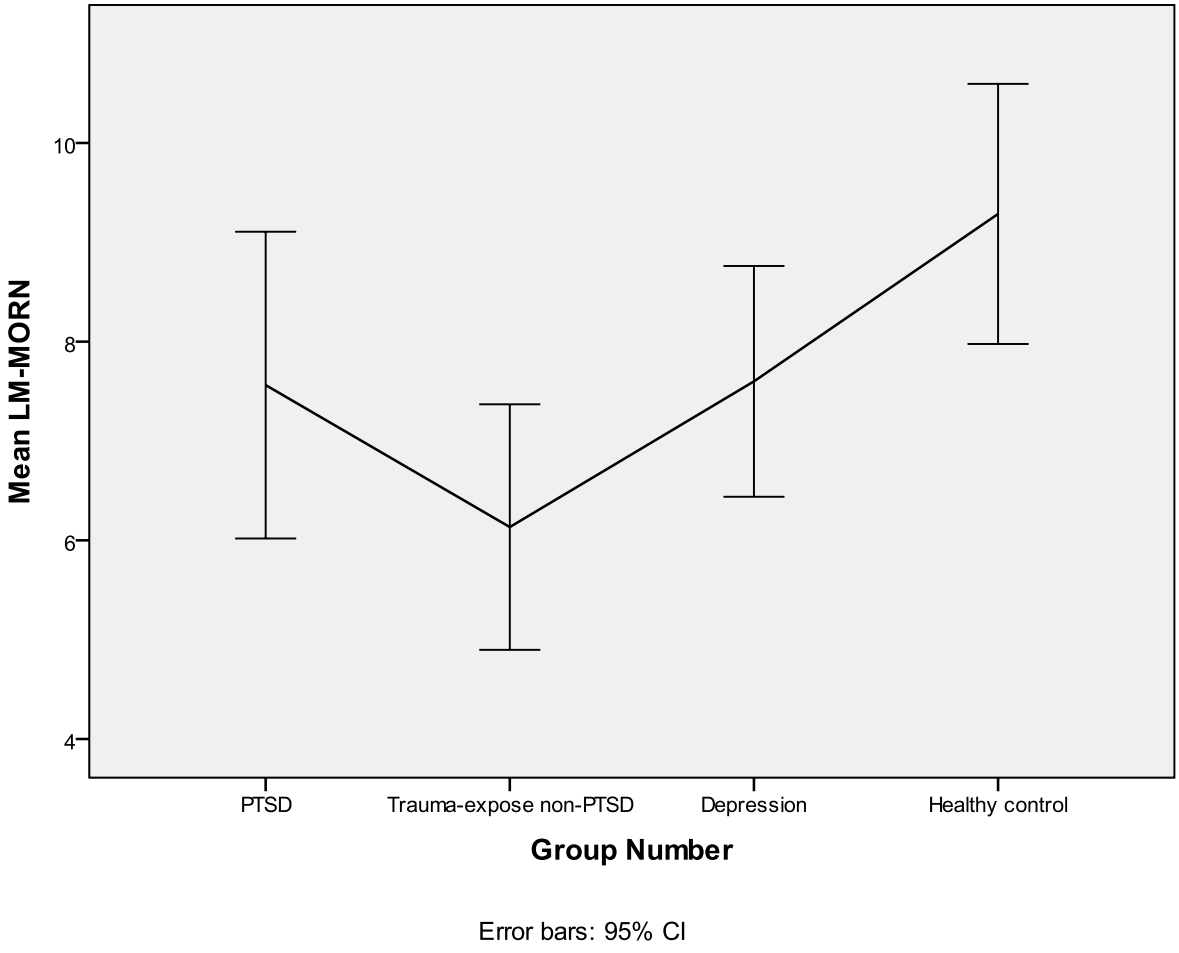

Figure 16. Group mean data for WMS-III Logical Memory post-sleep delayed recall. Error bars represent the 95% confidence interval.

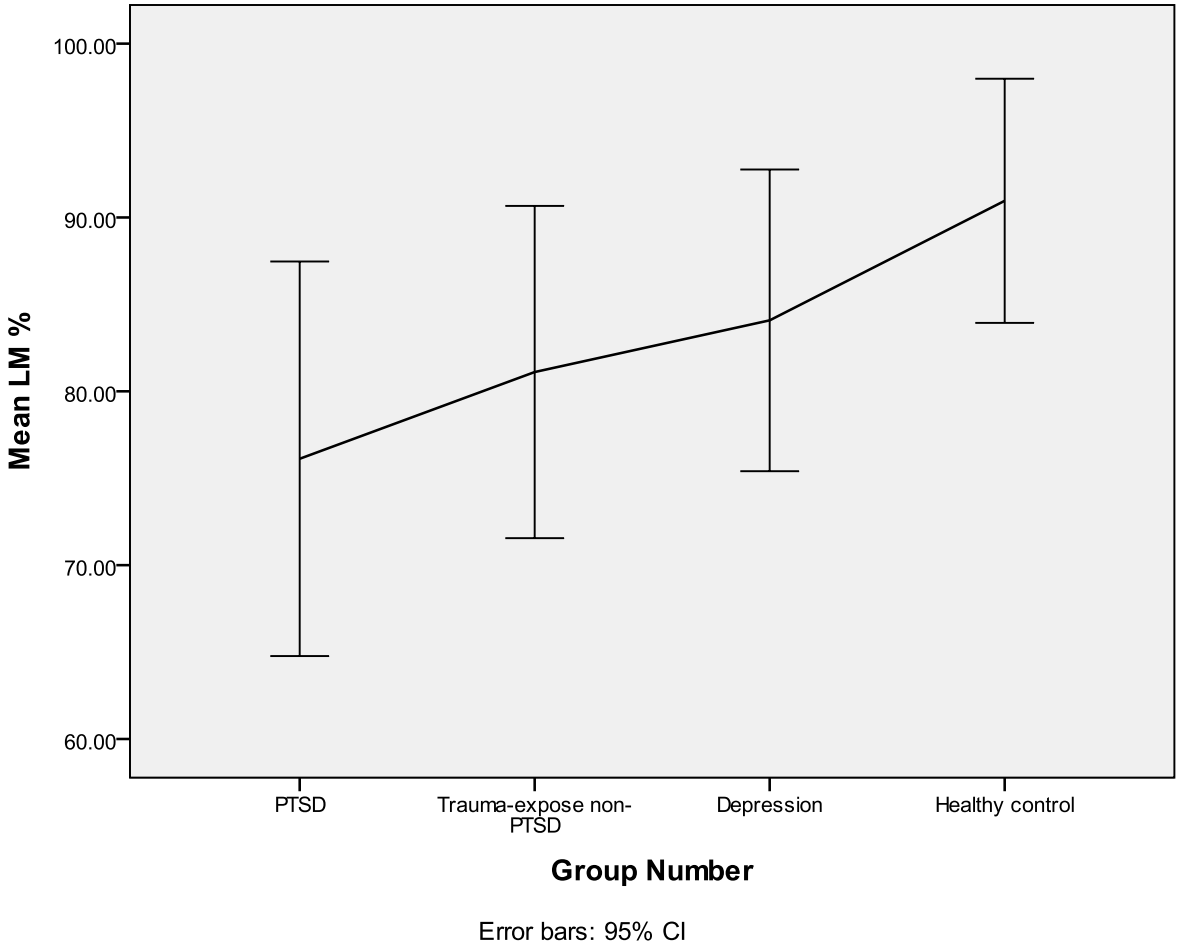

Figure 17. Group mean data for WMS-III Logical Memory percent retention. Error bars represent the 95% confidence interval.

Inferential statistical analyses of LM data. Table 9 shows the results of a series of one-way ANOVAs conducted on the three LM outcome measures. There were statistically significant between-group differences with regard to LM-MORN (delayed recall) and LM percent retention, and these were associated with small to medium effect sizes. There were, however, no statistically significant between-group differences with regard to LM-EVE (immediate recall), although the effect size here was not insubstantial.

The set of orthogonal planned comparisons outlined earlier were conducted on the data from the two outcome variables that delivered statistically significant ANOVA results. The results from those planed comparisons are shown in Table 10. The first contrast, for both LM-MORN and LM%, showed that the healthy control group performed significantly better (LM-MORN: $M = 9.3$, $SD = 2.27$; LM%: M = 11.2, $SD = 1.96$) than the other three groups taken together (LM-MORN: M = 7.1, SD = 2.41; LM%: M = 9.00, SD = 2.73). The second contrast, for both LM-MORN and LM%, showed that there were no statistically significant differences between the performance of the PTSD group and the trauma-exposed non-PTSD and the depression groups taken together. The third contrast, for both LM-MORN and LM%, showed that there were no statistically significant differences between the performance of the trauma-exposed non-PTSD group and the depression group.

With further regard to the LM-MORN data, Tukey's HSD post-hoc analysis was conducted because the first contrast does not provide specific information about which group(s) the healthy controls differed from. The Tukey's analysis revealed that the specific pairwise difference lay between the healthy control and trauma-exposed non-PTSD groups, with participants in the former group remembering significantly more of the stories than those in the latter group, $p < 0.01$. Thus, the set of a priori predictions was only confirmed in part.

With further regard to the LM% data, Tukey's HSD post-hoc analysis was conducted for the same reasons as for the LM-MORN data. This analysis revealed that the specific pairwise difference lay between the healthy control and PTSD groups, with participants in the former group retaining significantly more of what they had learned about the stories than those in the latter group, $p < 0.01$. Furthermore, the pairwise comparison of the healthy control group and the trauma-exposed non-PTSD group approached significance, suggesting that participants in the former group tended to retain more of what they had learned about the stories than those in the latter group. There, were, however, no statistically significant differences between the PTSD and

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the trauma-exposed non-PTSD groups, $p = 0.887$, suggesting that trauma, rather than PTSD per se, affected the retention of information after sleep. Furthermore, there were no statistically significant differences between the depression group and (a) the PTSD group, $p = 0.290$, (b) the trauma-exposed non-PTSD group, $p = 0.722$, and (c) the healthy control group, $p = 0.512$. This result is inconclusive as depressed participants did not perform better or worse than participants in any of the groups, suggesting that the relative influence of depression on between-group influences with regard to memory retention remains unknown.

In summary, no differences were found for LM-EVE suggesting that participants across all groups initially encoded and remember the stories similarly. The next morning, for LM-MORN, the trauma-exposed group remembered significantly less story information than healthy controls; however no differences were seen between healthy controls and the PTSD group. Thus limited support was found for hypothesis 2 which tested whether the relationship PTSD < trauma-exposed ? depressed < healthy control was true for general declarative memory recall. However hypothesis 3, which ascertained that the PTSD group would retain less information in comparison with baseline measures after a period of sleep, in comparison with healthy controls, was supported. The relationship PTSD < trauma-exposed ? depressed < healthy control was not proven in its entirety though as no differences between the PTSD and trauma-exposed non-PTSD groups were found, although this may be a question of sample size. However, since no differences between groups were detected at baseline, implying that all participants encoded the information similarly, the result that PTSD participants retained less information than healthy controls after a period of sleep is an important finding that warrants further investigation. Further, this result was associated with a medium effect size, suggesting that the sample-based estimate of the magnitude of the relationship between PTSD and declarative memory retention is not insubstantial, and that this relationship is therefore worthy of further study.

Inferential statistical analyses of FTT data. Previously published literature (see, e.g., Vasterling & Brailey, 2005) has shown that, while declarative memory performance is disrupted in PTSD, procedural memory performance is spared. The FTT was included as a measure in this study as a measure of procedural memory so that participant performance on it could be compared to performance on the declarative memory tasks (VPA, LM and AMT). Specifically, the aim here was to show that deficits in post-sleep memory retention are specific to declarative memory processes and do not include procedural memory processes.

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Table 9 shows that the a priori predictions with regard to procedural memory performance were confirmed: There were no statistically significant between-group differences with regard to FTP-EVE, FTP-MORN, or FTP% (i.e., all participants, regardless of group, learnt the digit sequence similarly, recalled it similarly, and showed similar levels of retention). The only point of interest is that all the retention percentages were over 100%, suggesting the strong procedural memory benefiting function of sleep that has been reported by many previous authors (see e.g., Fischer, et al., 2002; Walker, Stickgold, Alsop, Gaab, & Schlaug, 2005).

Trends in the AMT data: Cell-mean plots. Autobiographical memory represents a more personal aspect of declarative memory than that tested by conventional standardized tests, such as the VPA and LM tasks. In other words, tests such as the AMT focus on personal memories, rather than learnt semantic information (Williams & Broadbent, 1986). Therefore, administration of the AMT in studies such as this one does not necessitate pre- and post-sleep measurement, and so the only a priori predictions tested here were that (a) individuals diagnosed with PTSD would have poorer (i.e., less specifically detailed) memories for autobiographical events than participants in the other three groups, (b) healthy controls would have better (i.e., more specifically detailed) memories for autobiographical events than participants in the other three groups, and (c) There were no specific predictions with regard to the relative performance of the depression group, for reasons outlined earlier.

One participant from the healthy control group did not complete this test, and thus $n = 13$ for that group in the analyses of the data from this test. The cell-mean plot (Figure 18) suggests that, on average, participants in the healthy control group recalled the most specific memories, followed by participants in the depression group. On average, participants in the trauma-exposed non-PTSD group recalled the fewest specific memories, with participants in the PTSD group performing similarly poorly.

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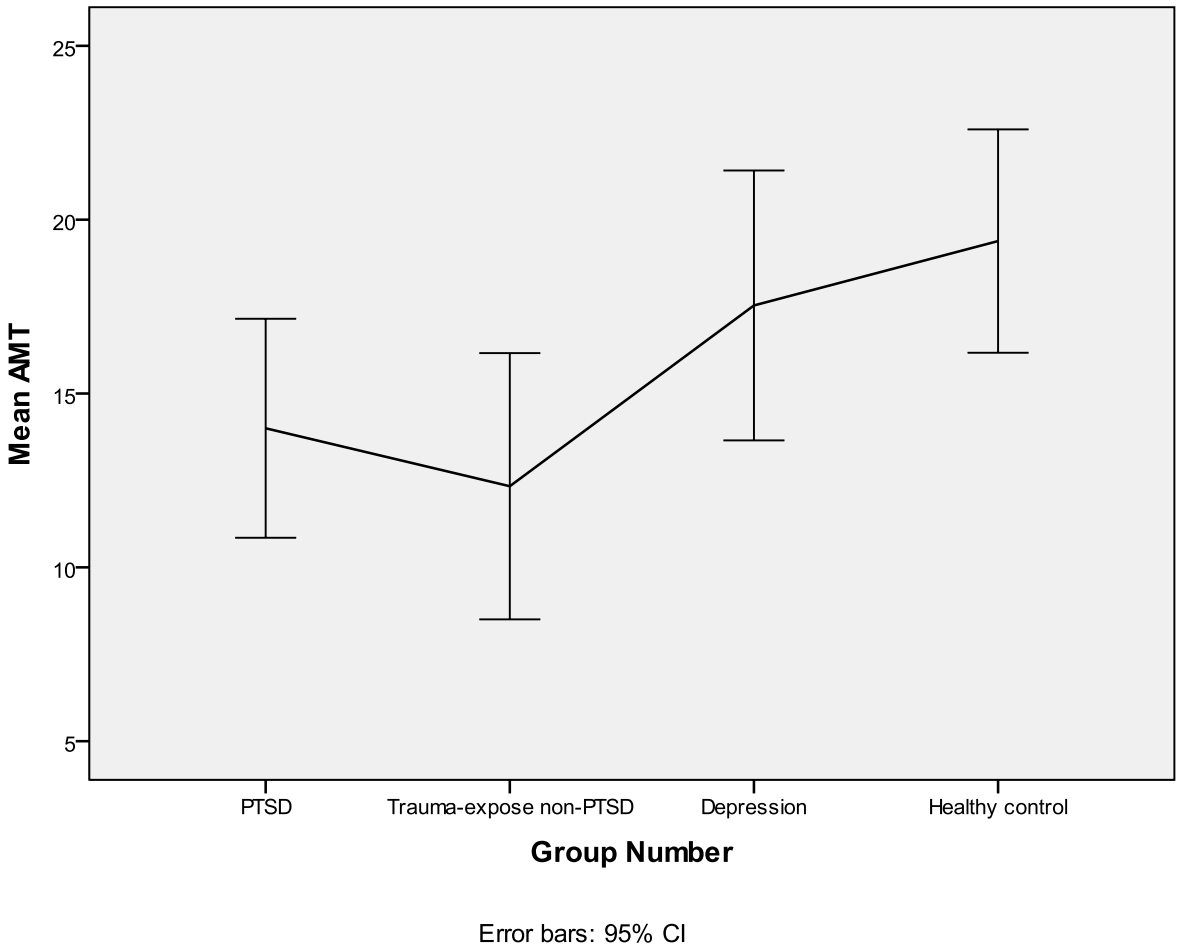

Figure 18. Group mean data for AMT total score. Error bars represent the 95% confidence interval.

Inferential statistical analyses of AMT data. Table 9 shows the results of a one-way ANOVA conducted on the AMT data. There were statistically significant between-group differences, and these were associated with medium effect sizes.

Hence, the set of orthogonal planned comparisons outlined earlier were conducted on the AMT data. Table 10 shows that, with regard to specificity of recalled autobiographical memories (a) healthy control participants (M = 19.53, SD = 5.32) performed significantly better, on average, than did PTSD, trauma-exposed non-PTSD, and depression participants taken together (M = 14.64, SD = 6.61), (b) there were no significant differences between PTSD participants and trauma-exposed non-PTSD and depression participants taken together, and (c) trauma-exposed non-PTSD participants (M = 12.33, SD = 6.91) performed significantly worse than depressed

participants (M = 17.53, SD = 7.01). Further post-hoc analysis, undertaken for reasons discussed above, revealed that (a) healthy control participants recalled significantly more specific memories than trauma-exposed non-PTSD participants, $p < 0.05$, and (b) there were no significant differences between the healthy control group and the PTSD group, $p = 0.118$.

In summary these results showed that in comparison with healthy controls, trauma-exposed non-PTSD individuals remembered less specific autobiographical memories. This result was not observed between PTSD participants and healthy controls. Thus only some support was found for hypothesis 2 which tested whether the relationship PTSD < trauma-exposed ? depressed < healthy control was true for specific autobiographical memory recall. However the cell-mean plots showed that the scores of the trauma-exposed non-PTSD and PTSD participants were very close - perhaps the smaller number of control participants resulted in limited power to determine differences between the PTSD and healthy control group. Further, unlike previous analyses, the results of this test did shed some light on the role of depression in PTSD and trauma with regard to memory performance. The results suggest that it is the experience of trauma, rather than depression that results in poor autobiographical memory recall, since depressed participants performed significantly better from trauma-exposed non-PTSD participants.

Interim Summary: Between-group differences in memory performance. Overall, the current data provided limited support for Hypothesis 2, which stated that (a) participants who have experienced trauma would, regardless of whether they are carrying a PTSD diagnosis or not, perform more poorly than healthy controls on declarative memory immediate recall and delayed recall tasks, (b) participants with a PTSD diagnosis would perform more poorly than those in the other groups on declarative memory immediate recall and delayed recall tasks, (c) healthy controls would show the best performance on declarative memory encoding and delayed recall tasks, and (d) there would be no between-group differences on measures of procedural memory.

With regard to immediate recall tasks, there were no between-group differences that fitted the a priori predictions. With regard to delayed recall tasks, only on the LM-MORN measure did trauma-exposed non-PTSD participants perform more poorly than healthy controls. The meaning of this finding is unclear, however, as PTSD participants did not perform more poorly than healthy controls. Nonetheless, the scores of the PTSD and trauma-exposed non-

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PTSD groups were similar on this measure, suggesting perhaps that the current analysis did not have enough power to detect group differences.

There were, however, no between-group differences on the measures of procedural memory, which confirmed one aspect of the a priori hypotheses. This piece of data suggests, then, that any between-group differences in encoding and delayed recall that did exist are specific to declarative rather procedural memory processing.

Overall, the current data provided some confirmation of Hypothesis 3, which stated (a) participants who had experienced trauma would, regardless of whether they were carrying a PTSD diagnosis or not, perform more poorly than healthy controls in terms of retention of declarative memory information, (b) participants with a PTSD diagnosis would perform more poorly than those in the other groups in terms of retention of declarative memory information, (c) healthy controls would show the best performance in terms of retention of declarative memory information, and (d) there would be no between-group differences on measures of procedural memory retention.

The most interesting results were obtained on the percent retention measure of the Logical Memory subtest. On that measure, PTSD participants performed significantly more poorly than healthy controls. Statistical trends also showed that trauma-exposed non-PTSD participants retained less information than healthy controls. There were, however, no differences in retention between PTSD and trauma-exposed non-PTSD participants, perhaps suggesting a specific role for trauma-exposure rather than PTSD per se.

There were no between-group differences on the measures of procedural memory retention, which confirmed one aspect of the a priori hypotheses. This piece of data suggests, then, that any between-group differences in retention that did exist are specific to declarative rather procedural memory processing.

Testing Hypothesis 4: Influences of sleep on memory

The analyses described above, in testing Hypotheses 1-4, suggest that, in PTSD, there is both disordered sleep and impaired declarative memory retention after sleep. Those analyses only hint at the role of sleep, however, because the design of the study did not include a group that stayed awake between initial encoding of to-be-remembered material and tasks testing retention of that material (i.e., a group that controlled for simple temporal degradation of

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memory). In other words, what is needed now is an analytic step that relates the disordered sleeping patterns to the memory retention deficits; this step will allow confirmation of the theoretical proposal that, in PTSD, disordered memory consolidation during sleep explains the pattern of impaired retention.

One way to take this analytic step is to examine, using regression models, the predictions made by Hypothesis 4 (i.e., that disordered sleep would (a) predict poor declarative memory performance, and (b) mediate the relationship between group membership and memory performance). Otherwise stated, this hypothesis predicts that individuals diagnosed with PTSD and who sleep badly will retain significantly less information across a sleep delay than controls.

The analyses so far, however, have established only that there is a trend towards disordered sleep in PTSD, and that that trend is most strongly expressed on measures of (i) sleep latency[7], (ii) the number of spontaneous arousals during the night, and (iii) percentage of SWS sleep. Because this trend toward disordered sleep in PTSD was not statistically significant, I knew, from the outset, that any further correlation/regression analysis would have limited power in predicting group-based memory performance from sleep variables. The analysis was conducted anyway to observe trends and perhaps suggest directions for future research.

More specifically with regard to the correlational/regression analysis, I created hierarchical regression models for only the memory variables for which Hypothesis 2 and/or Hypothesis 3 were confirmed (viz., LM post-sleep delayed recall (LM-MORN), LM percent retention post-sleep (LM%), and AMT total score). Similarly, the only sleep measures that were entered into regression equations as predictors were those that had approached statistical significance in the between-groups comparisons of sleep quality (viz., sleep latency, number of spontaneous arousal, and percentage of SWS).

Other variables that, based on previously published literature and theoretical insights, might have predicted memory performance in the current sample were also entered into the regression equations; these were PIQ, trauma severity, depression severity, and group status. These variable were entered into the regression equation in the same order as listed above. The sleep-related variables were entered next in a block.

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[7] Although sleep latency was shorter in PTSD participants in comparison with trauma-exposed non-PTSD and depression participants, the discussion will elaborate on why both increases and decreases in sleep parameters can be understood as markers of disordered sleep in PTSD.

The order of predictor entry into the regression equations was based on their temporal hierarchy in relation to the dependent variable. That is to say, having a particular PIQ (which is a reasonably stable measure across early adulthood) would occur before the occurrence of the trauma and before the development of depression (also reasonably stable measures), and so these variables would be entered into the equation earliest, in that order. Group status and sleep-related measures were products of the experiment, and thus had the closest proximity to the memory outcome measures, and thus were entered into the equation later.

In the regression analyses, each predictor variable was tested for significant R^2 change, and was only retained if that change was statistically significant. All analyses were assessed for (a) multi-collinearity, using VIF and tolerance values, (b) normality and homogeneity of variance, using histograms and probability plots, and (c) homoscedasticity, using scatter plots of the standardized predicted values versus the standardized residuals. All assumptions were met for the variables assessed, unless otherwise mentioned; in each case, however, the regression analysis proceeded in conventional fashion.

Regression Model 1: LM-MORN. The first analytic step here involved evaluating, in turn, each of these potential predictor variables: WASI PIQ scores, trauma severity (as measured by the CAPS), and depression severity (as measured by BDI score). This step was taken so that that the influence of group membership and sleep-related variables on LM post-sleep delayed recall could be determined after controlling for PIQ, trauma symptom severity, and depression symptom severity.

The analysis (see Table 11) showed that both PIQ and depression severity were significant predictors of LM-MORN, but that trauma severity was not. Thus trauma severity was excluded from all further analysis with regard to LM-MORN. After controlling for PIQ and depression severity, group status and the sleep-related variables were entered into the regression model.

Hence, the final set of independent (predictor) variables entered into the regression model for LM-MORN were:

Step 1: PIQ and depression severity

Step 2: Group membership (retained if ΔR^2 is significant, dropped if non-significant)

Step 3: Sleep-related variables (sleep latency, number of spontaneous arousals, and percentage of SWS)

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Table 11

Regression Analysis, LM-MORN: Data for post-sleep delayed recall, Logical Memory subtest

					Model		
	R^2	ΔR^2	*F* to enter / remove	ΔR^2 *p*	*df*	*F*	*p*
Step 1							
1.1 PIQ	.11	.11	6.99	.011*	1, 57	6.99	.011*
1.2 BDI	.21	.10	6.97	.011*	2, 56	7.35	.001**
Step 2							
2.1[a] PTSD versus HC	.29	.08	1.95	.133	5, 53	4.26	.003**
DP versus HC							
T-E versus HC							
2.2 T-E versus HC	.28	.08	5.85	.019*	3, 55	7.27	< .001**
Step 3							
3.1[a] Sleep latency	.34	.06	1.59	.202	6, 52	4.55	.001**
# spontaneous arousals							
SWS percentage							
3.2 SWS percentage	.34	.06	4.61	.036*	4, 54	6.97	< .001***

Note. PIQ = WASI Performance IQ score; BDI = Beck Depression Inventory-II score; HC = healthy control group; DP = depression group; T-E = trauma-exposed non-PTSD group.

[a]Dropped these combinations of predictors because ΔR^2 was not statistically significant, $p > .05$.

*$p < .05$. **$p < .01$. ***$p < .001$.

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Table 11 shows the results of the regression analysis for this outcome variable. After controlling for PIQ and depression severity, group membership did not add statistically significant predictive power to the model. On closer inspection, however, the comparison of the healthy control to the trauma-exposed non-PTSD group had a high zero-order correlation (r = .33), suggesting a moderate relationship with the outcome variable. Thus, that comparison was added alone at step 2. On analysis, belonging to the healthy control versus the trauma-exposed non-PTSD group added significantly to the variance in the model, and the variable was retained as a significant predictor of LM post-sleep delayed recall (see Table 12).

Thus, the predictors PIQ, depression severity, and healthy control versus trauma-exposed non-PTSD group membership were retained in the model, and the three sleep variables (sleep latency, number of spontaneous arousals, percentage of SWS) were entered to assess a possible mediational influence. Together, the sleep variables did not add any additional explanatory power. Percentage of SWS on its own, was a significant predictor of LM-MORN (Table 12), and was thus added alone at step 3 of the (Table 11).

On analysis, percentage of SWS added significant explanatory power to the model (Table 11), and was a significant predictor of performance on LM-MORN. Additionally, the overall regression model was a statistically significant good fit for the data, explained about 34% of the variance in performance. However, percentage of SWS was added to the model as a possible mediator; that is, when added to the model one expected that variable to explain some of the variance of the other predictors. This relationship was not observed: examining the part and partial correlations in comparison to the zero-order correlation (see Table 12), it is clear than none of the previous predictors have lost a large portion of their relationship with LM-MORN when percentage of SWS percentage is added to the model. This analysis suggests that percentage of SWS is not a mediator of the other predictors (and, specifically, of the hypothesized group membership).

Otherwise stated, the prediction tested here was that sleep variables would mediate group membership. This prediction was not confirmed. Further, the part and partial correlations for the percentage of SWS variable are larger than the zero-order correlation, indicating a suppression effect (i.e., this pattern of data suggests that percentage of SWS has a stronger relationship with LM-MORN performance when in combination with the other predictors).

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Table 12
Regression Analysis, LM-MORN: Statistically significant predictors

				Correlations		
	β	*t*	*p*	Zero-order	Part	Partial
Step 1						
Constant		1.88	.066			
PIQ	.317	2.66	.010*	.33		
BDI	-.314	-2.64	.011*	-.33		
Step 2						
2.1 Constant		2.47	.017*			
PIQ	.266	2.25	.029*	.33		
BDI	-.311	-1.63	.110	-.33		
PTSD versus HC	.015	0.06	.950	-.01		
T-E versus HC	-.290	-1.57	.123	-.33		
DP versus HC	-.044	-0.22	.828	< .01		
2.2 Constant		2.50	.016*			
PIQ	.267	2.30	.025*	.33		
BDI	-.312	-2.73	.008**	-.33		
T-E versus HC	-.281	-2.42	.019*	-.33		
Step 3						
3.1 Constant		2.09				
PIQ	.341	2.84	.006**	.33		
BDI	-.323	-2.87	.006**	-.33		
T-E versus HC	-.310	-2.57	.013*	-.33		
Sleep latency	.060	0.50	.622	-.09		
# spontaneous arousals	.046	0.38	.705	-.07		
SWS percentage	-.259	-2.18	.034*	-.12		
3.2 Constant		2.79	.007**			
PIQ	.329	2.83	.006**	.33	.36	.31
BDI	-.324	-2.93	.005**	-.33	-.37	-.32
T-E versus HC	-.290	-2.56	.013*	-.33	-.33	-.28
SWS percentage	-.246	-2.15	.036*	-.12	-.28	-.24

Note. PIQ = WASI Performance IQ score; BDI = Beck Depression Inventory-II score; HC = healthy control group; DP = depression group; T-E = trauma-exposed non-PTSD group.
*$p < .05$. **$p < .01$.

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Further analyses showed that SWS percentage only acted as a predictor when in combination with PIQ, depression severity and healthy control versus trauma-exposed group membership and that it's part and partial correlations were strengthened in comparison to the zero-order correlations. Several regression analyses were run with other combinations of the predictors identified as significant thus far and only the combination PIQ, depression severity and trauma-exposed group membership showed SWS percentage as a significant predictor.

With regard to the status of Hypothesis 4 given the data analyses reported in this section, there is partial confirmation of the first part of the hypothesis (one of the sleep-related variables - percentage of SWS) was a significant predictor of performance on LM post-sleep delayed recall. The second part of the hypothesis was disconfirmed, however: sleep-related variables did not mediate the relationship between group membership and performance on this memory task.

Taking into account the direction of the correlations reported for each predictor (positive or negative), the overall regression model suggested the following: the higher the PIQ, the better the memory performance (r = .33); the higher the depression score, the worse the memory performance (r = -.33); belonging to the trauma-exposed non-PTSD group was associated with worse memory performance (r = -.33; control: M = 9.29, SD = 2.27; trauma-exposed non-PTSD: M = 6.13, SD = 2.23); and that only if these relationships were met, would having a higher percentage of SWS result in poorer memory performance (r = -0.12). A summary statement might be, then, that individuals with relatively lower IQs, and who experience depressive symptoms, and who have experienced trauma, and who, in addition to all of these factors, have a higher-than-normal percentage of SWS, are at greater risk for performing more poorly on a delayed recall declarative memory task.

The LM-MORN variable, however, does not take into account initial learning and thus does not reflect the memory consolidation process adequately, for this we must turn to a measure which incorporates a comparison with baseline - the percentage of declarative memory retained after a period of sleep.

Regression Model 2: LM percent retention. This variable was of particular interest as this measure directly incorporates the effect of sleep as the value represents the percentage of retention after a period of sleep.

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The same sequence of analytic steps as described above for LM-MORN were undertaken in the regression analysis of percent retention, across a sleep-filled delay interval, on the WMS-III Logical Memory subtest.

First, the predictors PIQ, trauma severity, and depression severity were each evaluated in turn to determine their influence on post-sleep percent retention of originally encoded LM material. This time, however, the model including PIQ as a predictor was not statistically significant, $F(1, 57) = 0.25$, $p = .622$, perhaps because LM percent retention represents an amount of material recalled in relation to baseline performance, and is thus not an absolute value. Similarly, trauma severity was also not a statistically significant predictor of LM percent retention, $\beta = 0.19$, $p = .529$. Depression severity was, however, a statistically significant predictor here, $\beta = 0.33$, $p < 0.05$.

Hence, the final set of independent (predictor) variables entered into the regression model for LM percent retention were:

Step 1: Depression severity

Step 2: Group membership (retained if ΔR^2 is significant, dropped if non-significant)

Step 3: Sleep-related variables (sleep latency, number of spontaneous arousals, and percentage of SWS)

Table 13 shows the results of the regression analysis for this outcome variable. After controlling for PIQ and depression severity, group membership did not add statistically significant predictive power to the model. On closer inspection, however, none of the predictors at step 2 were significant (see Table 14), indicating that depression severity had become non-significant with the addition of group membership. Further the tolerance statistics were extremely low (see Table 14), indicating high levels of multi-collinearity; a healthy level of tolerance should approach 1 (Field, 2009).

This analysis, then, indicates that we cannot separate the effect of depression severity from group membership when explaining the variation in LM percent retention. Recall that the analysis on between-group differences in LM percent retention concluded that the role of depression severity on performance on that outcome measure was unclear. Hence, to proceed with the regression-based analysis one cannot have both group membership and depression severity in the model, because they are too inter-related. Because the ultimate goal here was to determine (a) whether sleep-related variables predict performance on declarative memory tasks,

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and, more importantly, (b) whether sleep-related variables mediate the relationship between group membership and performance on declarative memory tasks, depression severity was dropped as a predictor. At this point, then, the conclusion with regard to depressive symptomatology is that the current study can make no comment on its role in the relationship between sleep, trauma exposure, PTSD, and memory performance; future studies will have to address that question.

An analysis of the predictive power of group membership alone on LM percent retention revealed that this independent variable accounted for a statistically significant portion of the variance in performance on that outcome variable. Two group-based comparisons (PTSD versus healthy control, and trauma-exposed non-PTSD versus healthy control) were statistically significant predictors, whereas the comparison of depression versus healthy control was not (see Table 13). These results bear a striking similarity to the ANOVA results reported in the previous section. All three of these comparisons were retained, as a group, in the set of predictors, however, because when the depression versus healthy control comparison was removed, the predictor lost some significance, going from $\beta = .37$, $p < .05$ to: $\beta = .26$, $p = 0.054$.

At the next analytic step, the three sleep-related variables (sleep latency, number of spontaneous arousals, and percentage of SWS) were added to the regression model. These potential predictors did not, as a set, add additional explanatory power. Furthermore, none of the individual predictors were statistically significant or showed any promising correlations with LM percent retention.

In summary, then, only group membership predicted declarative memory retention (as measured by the WMS-III Logical Memory subtest, comparing immediate and delayed recall) after encoding and a sleep-filled delay interval, with the model a statistically significant fit for the data, $F(3, 56) = 3.747$, $p < 0.05$. With regard to the status of Hypothesis 4 given the data analyses reported in this section, the set of predictions was disconfirmed: sleep-related variables did not predict LM percent retention, and sleep-related variables did not mediate the relationship between group membership and performance on this memory outcome measure.

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Table 13

Regression Analysis, LM Percent Retention: Data for post-sleep retention, Logical Memory subtest

					Model		
	R^2	ΔR^2	*F* to enter / remove	ΔR^2 *p*	*df*	*F*	*p*
Step 1							
BDI	.11	.11	7.17	.010*	1, 58	7.17	.010*
Step 2							
2.1[a] PTSD versus HC	.17	.06	1.37	.261	4, 55	2.86	.032*
DP versus HC							
T-E versus HC							
2.2[b] PTSD versus HC	.17	.17	3.75	.016*	3, 56	3.75	.016*
DP versus HC							
T-E versus HC							
Step 3							
3.1[c] Sleep latency	.21	.04	0.88	.459	6, 53	2.30	.048*
# spontaneous arousals							
SWS percentage							

Note. BDI = Beck Depression Inventory-II score. HC = healthy control group; DP = depression group; T-E = trauma-exposed non-PTSD group.

[a]Problems with multicollinearity between group membership and BDI scores (see Table 15). [b]BDI dropped as predictor due to problems with multicollinearity. [c]Dropped these combinations of predictors because ΔR^2 was not significant $p > 0.05$.

*$p < .05$.

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Table 14
Regression Analysis, LM Percent Retention: Statistically significant predictors

	β	*t*	*p*	Tolerance	VIF
Step 1					
Constant		16.09	< .001***		
BDI	-.332	-2.68	.010*	1.000	1.000
Step 2					
2.1 Constant		15.37	< .001**		
BDI	-.114	-0.57	.574	0.368	2.718
PTSD versus HC	-.374	-1.51	.137	0.245	4.081
T-E versus HC	-.300	-1.54	.128	0.399	2.505
DP versus HC	-.128	-0.604	.548	0.335	2.983
2.2 Constant		16.06	< .001**		
PTSD versus HC	-.484	-3.17	.003**	0.636	1.571
T-E versus HC	-.368	-2.418	.019*	0.644	1.554
DP versus HC	-.211	-1.388	.171	0.644	1.554
Step 3					
Constant		6.68	< .001***		
PTSD versus HC	-.518	-3.32	.002**	0.615	1.626
T-E versus HC	-.474	-2.840	.006**	0.538	1.859
DP versus HC	-.266	-1.599	.116	0.540	1.853
Sleep latency	.164	1.226	.226	0.850	1.177
# spontaneous arousals	.150	1.137	.260	0.836	1.196
SWS percentage	-.103	-0.779	.440	0.857	1.167

Note. BDI = Beck Depression Inventory-II score; HC = healthy control group; DP = depression group; T-E = trauma-exposed non-PTSD group.
*p < .05. **p < .01. ***p < .001.

Even though the final regression model was statistically significant, it only explained 16.7% percent of the variation in LM percent retention, and left a large portion of the variation unexplained. Because the sleep-related variables only approached significance in the analysis of between-group differences reported earlier, it is likely that the regression model did not have enough power to relate the group differences observed in sleep characteristics and quality to the group differences observed in memory performance, thus leaving a large portion of variance unexplained. A larger sample, with more power, may be able to elaborate on the findings presented here.

Regression Model 3: AMT total score. The same sequence of analytic steps as described above for LM-MORN and LM percent retention were undertaken in the regression analysis of total score for number of specific memories produced on the Autobiographical Memory Test.

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First, the predictors PIQ, trauma severity, and depression severity were each evaluated in turn to determine their influence on AMT total score. An analysis of the initial predictors PIQ, trauma severity, and depression severity showed that only PIQ and depression severity were significant predictors of performance, while trauma symptom severity was not, $\beta = .05$, $p = 0.781$.

Hence, the final set of independent (predictor) variables entered into the regression model for AMT total score were:

Step 1: PIQ and depression severity

Step 2: Group membership (retained if ΔR^2 is significant, dropped if non-significant)

Step 3: Sleep-related variables (sleep latency, number of spontaneous arousals, and percentage of SWS)

Table 15 shows the results of the regression analysis for this variable. After controlling for PIQ and depression severity, group membership did not add statistically significant predictive power to the model. The change in R^2 approached significance, however, indicating a possible influence. Further inspection revealed that the comparison of the trauma-exposed non-PTSD group to the healthy control group had a moderate zero-order correlation ($r = .29$) with AMT total score, indicating a possible influence. Thus, that comparison was added alone at step 2. On analysis, belonging to the healthy control versus the trauma-exposed non-PTSD group added additional explanatory power, and the variable was retained as a significant predictor of AMT total score.

At the next analytic step, the predictors PIQ, depression severity, and the comparison of trauma-exposed non-PTSD group membership versus health control group membership were retained in the model, and the three sleep variables (sleep latency, number of spontaneous arousals, and percentage of SWS) were entered to assess possible mediational influences. Together, the sleep variables did not add additional explanatory power. Inspection of the zero-order and part and partial correlations also did not allude to any potential for these variables to add any predictive power to the model (Table 16).

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Table 15
Regression Analysis, AMT Total Score

					Model		
	R^2	ΔR^2	*F* to enter / remove	ΔR^2 *p*	*df*	*F*	*p*
Step 1							
PIQ	.09	.09	5.58	.022*	1, 56	5.58	.022*
BDI	.24	.15	11.19	.001**	2, 55	8.89	< .001***
Step 2							
2.1[a] PTSD versus HC	.34	.09	2.43	.076	5, 52	5.29	0.001**
DP versus HC							
T-E versus HC							
2.2 T-E versus HC	.30	.06	4.30	.043*	3, 54	7.72	< .001***
Step 3							
3.1[a] Sleep latency	.31	.01	0.13	.945	6, 51	3.73	.004**
# spontaneous arousals							
SWS percentage							

Note. PIQ = WASI Performance IQ score; BDI = Beck Depression Inventory-II score. HC = healthy control group; DP = depression group; T-E = trauma-exposed non-PTSD group.
[a]Dropped these combinations of predictors because ΔR^2 was not significant.
$p > 0.05$.*$p < .05$. **$p < .01$. ***$p < .001$.

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Table 16
Regression Analysis, AMT Total Score: Statistically significant predictors

	β	*t*	*p*	Zero-order correlation
Step 1				
Constant		1.54	.130	
PIQ	.284	2.42	.019*	.30
BDI	-.392	-3.35	.001**	-.41
Step 2				
2.1 Constant		1.86	.068	
PIQ	.246	2.14	.037*	.30
BDI	-.558	-3.00	.004**	-.41
PTSD versus HC	.207	0.91	.368	-.15
T-E versus HC	-.059	-0.33	.744	-.29
DP versus HC	.315	1.62	.112	.16
2.2 Constant		2.05	.045*	
PIQ	.241	2.08	.042*	.30
BDI	-.391	-3.43	.001**	-.41
T-E versus HC	-.240	-2.07	.043*	-.29
Step 3				
Constant		1.46	.152	
PIQ	.255	2.05	.046*	.30
BDI	-.391	-3.34	.002**	-.41
T-E versus HC	-.264	-2.10	.040*	-.29
Sleep latency	.074	0.59	.559	-.04
# spontaneous arousals	.039	0.31	.758	-.04
SWS percentage	-.017	-0.14	.888	-.02

Note. PIQ = WASI Performance IQ score; BDI = Beck Depression Inventory-II score; HC = healthy control
group; DP = depression group; T-E = trauma-exposed non-PTSD group.
*$p < .05$. **$p < .01$.

In summary, then, only PIQ, depression severity, and belonging to the trauma-exposed non-PTSD versus the healthy control group predicted AMT total score. The analysis did not support the prediction that sleep-related variables would mediate the relationship between group membership and recall of specific autobiographical memories, indicating that perhaps the consolidation of personal episodic memories is not contingent on sleep quality/characteristics. It is perhaps more likely that performance on the AMT reflects a retrieval process, given that participants retrieved memories from anytime in their lives rather than recently-consolidated memories. Because sleep acts on the consolidation of recently-encoded events, an autobiographical memory task that evaluated personal experiences during the experimental

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session and incorporated a before- and after-sleep measurement to examine consolidation during sleep could yield different results.

Summarizing results of Hypothesis 4. Overall limited support was found for this hypothesis which stated that disordered sleep would (a) predict poor declarative memory performance, and (b) mediate the relationship between group membership and memory performance. Only for LM-MORN did SWS percentage predict memory performance, but only in combination with other predictors. Further sleep parameters did not mediate group membership for memory performance.

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DISCUSSION

This study set out to investigate whether poor sleep quality in PTSD diagnosed individuals is a mechanism explaining deficits in declarative memory in this population, based on the current knowledge that sleep benefits memory consolidation in healthy individuals. To do this it was necessary to establish whether and to what extent individuals diagnosed with PTSD in comparison to trauma-exposed non-PTSD, depressed and healthy participants, showed signs of poor sleep quality (hypothesis 1). By improving on methodological flaws from previous studies, this project aimed to clarify the inconsistent results from previous studies. This question was investigated using sleep adapted EEG in the sleep laboratory. Secondly this study aimed to replicate a largely consistent body of literature that shows that individual diagnosed with PTSD show declarative memory deficits (hypothesis 2). Before and after sleep, measures of declarative memory (and procedural memory as a control for the type of memory) were taken to replicate these findings and to investigate the main hypothesis of this study – that poor sleep is a mechanism that underlies poor declarative memory performance in PTSD. To investigate the main hypothesis I compared the memory retention scores (which compared the amount of information recalled post-sleep to the amount of information recalled pre-sleep) of PTSD diagnosed individuals to those from the other groups (hypothesis 3). I also examined whether sleep parameters predicted memory performance and whether sleep parameters mediated group membership for memory performance – put simply, whether PTSD individuals that sleep poorly, show declarative memory deficits (hypothesis 4).

In this section I will begin by highlighting the methodological issues this study addressed and the merit of the study design. Next I will explore the findings from the sleep data, followed by the findings from the memory data. Lastly I will relate to what extent poor sleep can be understood as a mechanism underling poor declarative memory in PTSD.

Addressing Methodological Problems Inherent in Previous Studies

This research demonstrated the value and importance of closely analyzing the methodological weaknesses of previously published studies, and then attempting to address as many of them as possible in a single strongly-designed new study.

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Where many previous research studies have compared sleep characteristics and/or memory performance in PTSD to either a healthy control group (see e.g., Fuller, et al., 1994; Hurwitz, et al., 1998; Mellman, Kumar, et al., 1995) or to a group of individuals with a history of trauma exposure but not PTSD diagnosis (Dagan, et al., 1997; Engdahl, et al., 2000; Klein, et al., 2002), but not both, the current study included both a healthy control group and a trauma-exposed non-PTSD group. Such a design is important if one is to characterise adequately differences between individuals who have not recovered from a traumatic event (and hence can be diagnosed with PTSD) to those who have recovered but still have some mild symptoms, and to those with no previous experience of trauma and no psychiatric symptoms. Further one cannot simply assume that PTSD, rather than the experience of trauma itself, governs the severity of, for example, disordered sleep or memory deficits – this assumption should be tested empirically by including both a trauma-exposed non-PTSD and healthy control group.

With regard to participants' age range, the current study included only participants with a minimal likelihood of experiencing age-related sleep changes (i.e., participants who were younger than 40 years old), such as longer sleep latency, lower sleep efficiency, more frequent awakenings, and decreased amounts of SWS and REM sleep. Previous research has shown that age-related changes are sometimes observed as early as 35 years of age, but that they generally occur from around 40 years and increase through the 50s and 60s (Blackman, 2000; Carrier, Land, Buysse, Kupfer, & Monk, 2001; Gaudreau, Carrier, & Montplaisir, 2001). A meta-analysis of PTSD sleep studies showed that the mean age of participants across studies was 42.4 years, with 9 of the 19 studies in the sample featuring participants with a mean age of more than 42 years (Kobayashi, et al., 2007). In such studies, then, it might be difficult to make distinctions between whether (or to what extent) the observed disordered sleep quality is accounted for by age-related sleep changes or by PTSD- or trauma-related influence.

With regard to participants' time since trauma, the current study featured strong restrictions on the amount of time that could have passed between the participant's experience of trauma and her enrollment into the study (minimum 6 months, maximum 5 years). The PTSD and trauma-exposed non-PTSD groups were well matched on this criterion (mean time since trauma for the PTSD participants = 2.33 years, *SD* = 1.75; for trauma-exposed non-PTSD, *M* = 1.67 years, *SD* = 1.10). The restricted range for time since trauma was used because, the shorter the time between trauma exposure and participation, the fewer covariant factors are likely to

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influence either the pattern of disordered sleep or the pattern of memory deficits. In terms of the upper age limit set for this study it is substantially lower than most previous studies on war veterans, where the mean time between trauma and study participation, with few exceptions, is between 25 and 50 years ago (see e.g., Engdahl, et al., 2000; Mellman, et al., 1997; Ross, et al., 1994).

With regard to the sex of participants, the current study included women only. Although a balanced and representative sample is ideal, most previous studies have, as noted earlier, focused on male war veterans (Kobayashi, et al., 2007). Other areas of PTSD research have shown substantial sex differences between men and women – for example, that women rather than men are more likely to develop PTSD in the aftermath of traumatic experience (Holbrook, Hoyt, Stein, & Sieber, 2002). It is unknown whether the mechanisms underlying this sex difference influence other domains such as sleep. More studies that feature female-only samples can serve to redress that imbalance, and might allow meta-analysts to explore sex differences in their reviews of the field.

With regard to participant substance abuse history, the current study excluded individuals with histories of alcohol and/or other drug abuse in the 12 months prior to enrollment. Research has shown that alcohol and/or drug abuse is associated with specific patterns of disordered sleep (Roehrs & Roth, 2001) as well as progressive memory decline (Riege, Holloway, & Kaplan, 1981), which may confound the effects of PTSD and trauma on sleep quality and memory performance. Hence, the current results are not confounded by the possibility that alcohol and drugs may account for differences in sleep quality and memory performance.

With regard to depression, the current study controlled for occurrence and severity of depressive symptomatology by including a depression-only group to compare with the PTSD and trauma-exposed non-PTSD groups, which, as clinical lore and previous literature suggested they would (Hofmann, Litz, & Weathers, 2003), were both characterised by high levels of (comorbid) depression. Whereas epidemiological studies from the United States have reported a 48.3 % rate of comorbid depression with PTSD (Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995), in the current sample only 4 out of the 31 PTSD and trauma-exposed non-PTSD participants were *not* depressed, according to the BDI. In other words, the rate of comorbidity was 87.1 %.

Other South African studies have also reported high rates of comorbid depression in PTSD. For example, Carey, Stein, Zungu-Dirwayi, and Seedat (2003), in a study conducted

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using a sample from a primary health care clinic, found a 75% prevalence rate of depression in a group of individuals diagnosed with PTSD. In that sample, a diagnosis of PTSD was also associated with higher levels of poverty, and it is likely that the elevated levels of depression associated with PTSD in South African communities are related to high levels of poverty and unemployment – previous research has shown higher prevalence rates of depression in poorer communities (Galea, et al., 2007). These contextual factors may not play as strong a role in developed-world settings. Thus, developing-economy countries such as South Africa, it may not be possible to find a large sample of individuals with PTSD and no comorbid depression (and, indeed, it is almost certainly not clinically relevant to study such a sample).

Although the optimally-designed study would compare a PTSD group to a group of PTSD patients with no comorbid depression group and to group of PTSD patients with comorbid depression, the realities of the South African context meant that the best design for the current study was one in which PTSD and trauma-exposed groups, both with comorbid depression, were compared to depression–only participants. This comparison is particularly necessary when attempting to describe the associations between disordered sleep parameters and PTSD, given that depressive symptoms are associated with their own set of disordered sleep parameters, including decreased SWS, decreased REM latency, and increased REM (Franzen & Buysse, 2009).

In summary, then, the current study attempted to avoid the methodological flaws present in previously published studies in this field by including most of the appropriate control groups (trauma-exposed non-PTSD, depression-only, and healthy control), young adults with minimal likelihood of age-related sleep changes, and a female-only sample; additionally, the eligibility criteria specified that participants in the PTSD and trauma-exposed non-PTSD groups had to have a relatively short time between trauma experience and study participation, and that all participants were to have shown no signs or symptoms of substance abuse or dependence in the 12 months prior to enrollment. These extensive control conditions and stringent eligibility criteria are especially important to employ in sleep studies, which typically feature small sample sizes due to the time and resource-intensive nature of the data collection. These small samples sizes mean one must minimize, at the design level, any potential covariates.

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Hypothesis 1: Findings regarding sleep quality

Although the overall aim of this research was to characterise sleep differences between PTSD participants and those without PTSD, for the purpose of comparison with the memory data, the sleep data were analysed in their own right because the literature surrounding disordered sleep in PTSD is so inconsistent. In other words, characterizing disordered sleep in PTSD (indeed, being able to answer the question of whether, in fact, there *is* disordered sleep in PTSD) not only had the potential to help address the broader interests of the study but also had the potential to help shed light on three decades of inconsistent findings in the PTSD sleep literature. Hence, the first set of analyses in the current study tested the hypothesis that the participants who had experienced trauma, but particularly those with a PTSD diagnosis, would have poorer sleep quality than healthy controls.

Overall the statistical analysis from the sleep-related variables did not confirm hypothesis 1 – that is (a) in comparison with all the other groups PTSD participants did not have poorer sleep quality; (b) the sleep quality of sleep for the trauma-exposed non-PTSD and depression groups did not fall between the PTSD and healthy control groups and (c) the healthy control group did not have the best sleep quality in comparison to all the other groups.

However trends in the data suggested poorer sleep in PTSD and trauma based both on statistical analysis and trends suggested by cell-mean plots of the data (see figures 3-10). In terms of the latter, the majority of variables depicted poorer sleep in PTSD (five out of eight variables – sleep efficiency, the number of awakenings, time awake after sleep onset, REM percentage and REM latency) in comparison with all the other groups. For a sixth variable, the number of spontaneous arousals, PTSD participants had marginally lower frequencies of arousals than the trauma-exposed non-PTSD participants – both these groups showed more frequent arousals than either depression or healthy control participants.

The results of inferential statistical analysis showed that only sleep latency, the number of spontaneous arousals and SWS percentage approached statistical significance, indicating possible group differences. On further analysis, contrary to predictions, PTSD participants had a shorter sleep latency than the trauma-exposed non-PTSD and depressed individuals. However in terms of the number of spontaneous arousals and SWS percentage, there was a reasonable trend towards confirming the hypotheses about poorer sleep quality in PTSD and trauma-exposed non-PTSD participants, although these results must be interpreted with caution since (a) omnibus

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ANOVA results only approached significance, (b) trends for decreased SWS percentage in PTSD and trauma-exposed non-PTSD were based on the pooled variance of PTSD, trauma-exposed non-PTSD and depression participants. However, these results do, to an extent, confirm the results of previous studies, which have indicated a trend towards worse sleep in PTSD, but with relatively small actual differences. The following section will explore possible reasons for (a) the relatively small differences indicating poorer sleep quality in individuals diagnosed with PTSD and (b) possible explanations for inconsistent finding such as shorter sleep latencies in PTSD (suggesting better sleep) in comparison with a trend towards more frequent spontaneous arousals and less SWS percentage (suggesting poorer sleep).

Further the discussion will draw on trends observed in the data. Although these trends must be interpreted with caution (since they do not represent statistical findings), the inferential statistics provided limited support for hypothesis 1, possibly because of limited power to detect group differences due to a small sample. That is, in light of the relatively subtle group differences, inferential statistics may be a relatively blunt tool. Despite the limited statistically findings, some interesting trends and patterns emerged from the data that warrant further discussion and investigation.

A review of the literature suggested two possible reasons for trends in poorer sleep quality in PTSD, with relatively small actual differences, in contrast with widely reported sleep difficulties (Neylan, et al., 1998; Ohayon & Shapiro, 2000). The first, reason involves the plethora of methodological issues outlined in the previous section; the second reason involves the hypothesized struggle between hyperarousal states and the homeostatic- and circadian-generated pressure to sleep, which results in deeper sleep once individuals diagnosed with PTSD have fallen asleep. Because this study addressed many of the methodological shortcomings of previous studies, a further examination of the latter reason is necessary. Several patterns in the data suggest some support for oscillation between hyperarousal and the pressure to sleep.

Drawing on the results of tests of the assumptions underlying inferential statistical analyses to ascertain the properties of the sleep data, the Kolmogorov–Smirnov test showed that, in particular, data from the PTSD and trauma-exposed non-PTSD groups violated the assumption of normality; the distributions of sleep-related data for these groups were particularly uneven (see Figure 19; it presents a histogram for each group's sleep latency data, serving as an example of this uneven distribution pattern.). Although it is likely that distributions will appear non-

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normal with small sample sizes, it is of value to note that data drawn from the two groups of participants with trauma exposure consistently violate this assumption, whereas data drawn from the depression and healthy control groups do not.

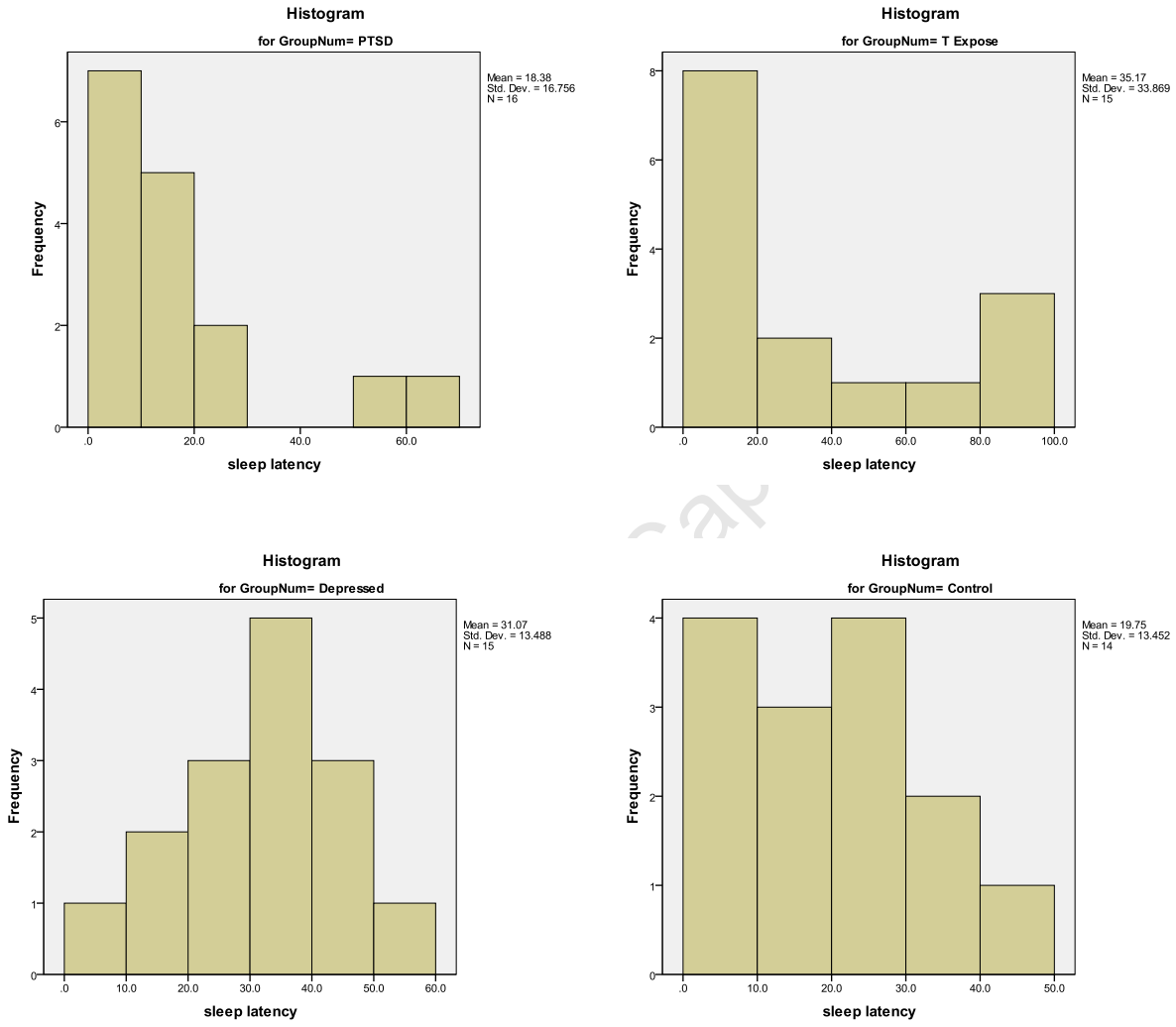

Figure 19. Distribution of sleep latency by group. The top left panel of the figure shows data from the PTSD group; the top right panel shows data from the trauma-exposed non-PTSD group; the bottom left panel shows data from the depression group; and the bottom right panel shows data from the healthy control group.

Although one might expect the sleep data to be skewed for healthy adults, who generally take around 10 minutes to fall asleep under normal conditions (i.e., observed values should cluster around that population mean value), it is apparent from the histograms that the PTSD and

trauma-exposed groups do not have even distributions like the depression and healthy control groups do; the latter groups do, indeed, show an even distribution around the highest frequency value. Overall, the distributions for the PTSD and trauma-exposed non-PTSD groups suggest that although many participants fall asleep quickly, another cluster forms on the other side of the spectrum; that is, a proportion of participants take a long time to fall asleep, resulting in an uneven distribution.

These patterns of distribution suggest that participants in the PTSD and trauma-exposed non-PTSD groups show, at least with respect to some sleep-related variables, a large variation in sleeping patterns that can be described as tending towards the extreme poles of the sleep scale – either sleeping far better (e.g., falling asleep quickly) or sleeping far worse (e.g., taking much longer to fall asleep). Previous studies (e.g., Pillar, et al., 2000) have also reported that the most extreme values for sleep variables are found in PTSD participants.

Such data, then, suggest an oscillation between poor sleep and good sleep, which can be hypothesized to result from oscillation between a hyperarousal state and homeostatic- and circadian-driven pressure to sleep. This pressure to sleep leads to over-compensation following a period of sleep restriction, which may account for the times when PTSD participants appears to be sleeping far better than healthy controls.

Other patterns in the sleep data might also be interpreted as supporting the hyperarousal-pressure to sleep oscillation theory. For example, the cell-mean plots for the sleep latency and the number of awakenings variables suggest that, although PTSD participants tended to fall asleep more quickly than other participants, they also woke up during the night more frequently. In contrast, trauma-exposed non-PTSD participants took a long time to fall asleep, but woke less frequently during the night. Bearing in mind that cell-mean plots only depict trends, and that conclusive evidence confirming or disconfirming theoretical predictions should be based on models derived from inferential statistical analysis, this trend suggests oscillation between poor and better sleep in PTSD and trauma and therefore some speculatory support for the oscillation in sleeping patterns based on hyperarousal and sleep compensation. That is PTSD participants fell asleep faster (supported by statistical trends for sleep latency), possibly because of a compensatory pressure to catch up on sleep and their subjective perception of safety at the laboratory, but their state of hyperarousal interrupted the continuity of their sleep. Additionally and similarly, one might speculate that the state of hyperarousal experienced by participants in

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the trauma-exposed non-PTSD group kept them awake for longer, but when they did fall asleep, the homeostatic- and circadian-driven pressure to sleep ensured that they woke up less frequently during the night. This theory can also account for the contradictory statistical trends – that is, participants in the PTSD group tended to fall asleep quicker, but overall trends suggest poorer sleep for these individuals.

Although these interpretations are speculative, the data for the PTSD and trauma-exposed non-PTSD groups once again shows variations toward the extremes: Participants in the PTSD group fell asleep the quickest and had the most awakenings, while participants in the trauma-exposed non-PTSD group took the longest time to fall asleep and had the fewest awakenings. This systematic pattern of hugging the extreme ends of 'best' and 'worst' suggests an oscillation between better and worse sleep, and can be explained by a continual struggle between a state of hyperarousal state and the pressure to sleep. This pattern of oscillation between better and worse sleep may act to moderate data when groups of participants with a trauma history are studied: those who, at the time of the study, are sleeping better due to compensation for previous poor sleep might be in the same group as those who, at the time of study, are sleeping poorly due to a state of hyperarousal. Obviously, these speculative interpretations need empirical study.

Again bearing in mind that the above speculation is based largely on trends observed in the distribution of the data and cell-mean plots, there has to be some discussion as to why inferential statistical analyses failed to detect any statistically significant between-group differences. Two methodological issues may help to account for that failure: sample size and environmental factors.

First, with regard to sample size, each of the groups consisted of a relatively small number of participants (14-16), and therefore it is possible that the sample sizes were simply not large enough to generate enough power to detect, at a statistically significant level, what might be relatively small effects. For instance, it is fairly well established in the literature that individuals diagnosed with a major depressive disorder have lower SWS percentage, higher REM percentage, and a shorter REM latency than healthy controls. Although this trend was observed in the cell-mean plots, inferential analyses did not reach statistical significance, suggesting that a larger sample is necessary to obtain significant results in the predicted direction. Furthermore, although the effect sizes for variables that approached statistically significant group differences (sleep latency, number of spontaneous arousals and SWS

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percentage) were medium in size for the overall analysis (r = 0.33, 0.35, 0.33, respectively), they were small for more specific planned comparisons, suggesting that a larger sample is needed to (a) reach statistical significance, and (b) clarify the direction of group differences.

Second, with regard to environmental factors, cell-mean plots of subjective reports showed that participants in the PTSD group rated their sleep quality in the lab higher than did participants in the other groups. Inferential statistical analysis of these subjective data approached significance with regard to between-group differences. Upon further questioning, participants in the PTSD and trauma-exposed non-PTSD groups, in particular, accounted for their high ratings by saying that they felt safe in the sleep laboratory. This unexpected finding may have particular local significance: the sleep laboratory environment is, in all probability, safer than participants' home environments - this difference might be particularly salient for those who have experienced trauma. From the perspective of the fidelity of the observed data, if participants who had experienced trauma did indeed sleep better on the night of the experiment, the environment might have moderated a true reflection of individuals' objective sleeping patterns.

Thus, the lack of statistically significant between-group differences in this study might be accounted for by an inadequate sample size and/or the impact of environmental factors on sleep patterns, rather than by the oscillation between hyperarousal and the pressure to sleep. However, it may also be true that individuals who have been diagnosed with PTSD, or who have been exposed to trauma, do have overall worse sleep quality (and that methodologically sound studies with an adequate sample size can demonstrate that fact), and that the extent of their poor sleep is moderated by the oscillation between hyperarousal and the pressure to sleep; these two hypotheses are not necessarily mutually exclusive. Clearly, more well-designed and methodologically sound empirical research is needed to explore the exact nature of the relationship between PTSD and disordered sleep.

Specific between-group differences. Two key questions arise around the nature of specific group differences with regard to the sleep literature in PTSD. The first is whether an experience of trauma results in disordered sleeping patterns, or whether a diagnosis of PTSD is especially related to disordered sleep. Many previous studies have only examined the difference between PTSD and healthy control groups, and have taken for granted the fact that it may be the

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experience of trauma that underlies disordered sleep. This is an assumption that should be empirically tested, however, and the current study set out to do just that.

Unfortunately, as noted above, there was a distinct lack of statistically significant findings with regard to specific between-group differences in sleep characteristics and quality, and so at this stage it would be premature to draw conclusions about the nature of the relationship between trauma exposure and a psychopathological response to trauma (i.e., PTSD) for sleep parameters. Future research should aim to address this question, however.

The second key question that arises here is the role that depressive symptomatology plays in the relationship between disordered sleep and PTSD/trauma exposure. Because depression is highly comorbid with PTSD, and is associated with its own specific pattern of disordered sleep, it would be valuable to ascertain to what extent the sleeping patterns of PTSD-diagnosed and trauma-exposed non-PTSD individuals are similar or different to those of depressed individuals. Although data from the current study did not replicate those reported in previously published studies, these studies show that depression is characterised by decreased SWS percentage, decreased sleep latency and increased REM percentage (Franzen & Buysse, 2009). This exact trend was observed in the cell-mean plots generated from the current data, but inferential statistical analyses of between-group differences did not reach statistical significance.

What is clear from the current data, however, is that trends observed in the data from the PTSD participants do not follow those of previous studies of depressed individuals. Instead, the current data, taken together with findings from previous studies of sleep in depression and in PTSD, suggest, that perhaps sleep in PTSD is characterised by oscillation of poor and better sleep across a number of sleep variables, while sleep in depression is characterised by a stable pattern of decreased SWS, decreased REM latency, and increased REM percentage. This is interpretation is, however, purely speculative at this stage and further research is needed to clarify sleep differences between PTSD and depression.

Summarizing sleep findings. In summary, the results have not clarified previous inconsistencies in the literature – this study has replicated a trend towards worse sleep in PTSD with relatively small differences between PTSD participants and the other groups. However this study did exclude potential covariates that other studies did not control for and therefore ruled out factors such as age-related sleep changes and alcohol abuse accounting for the results. Overall trends in the data suggest some support for the oscillation between a state of

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hyperarousal and compensatory pressure to sleep. This theory needs more systematic exploration by future studies. Further some methodological factors may account for the lack of findings – the small sample that the present study used as well as environmental factors associated with the sleep laboratory environment.

Recall, however, that the major aim of this research project is to examine disordered sleep as a mechanism underlying deficits in declarative memory in PTSD. In terms of memory consolidation, the sleep data presented above do suggest there might be an overall disruption in the integrity of the successive passage of sleep stages in PTSD as suggested by the some statistical trends, in particular for the number of spontaneous arousals and the percentage of SWS, as well trends observed in the cell-mean plots. The following sections will examine (a) whether PTSD participants have deficits in declarative memory and (b) to what extent the observed sleep differences explored above help explain declarative memory deficits in PTSD.

Hypothesis 2 and 3: Findings regarding memory performance

Overall four tests of memory were assessed – three for declarative memory (VPA, LM and AMT) and one for procedural memory (FTP). Three of the tests – VPA, LM and FTP measured memory performance before sleep (initial learning and encoding) and after sleep (delayed recall). The initial learning and encoding score was considered the baseline score. To ascertain the retention of a particular test after sleep, the percentage of delayed recall over encoding was calculated to take into account baseline measures and the period of sleep.

Group differences in encoding and delayed recall scores formed the basis of hypothesis 2, which posited that the two trauma groups and in particular the PTSD group would show deficits in encoding and delayed recall of declarative memory tasks in comparison with healthy controls. The performance of depressed participants was hypothesized to fall between that of the PTSD and healthy control group. Group differences in the percentage of retention formed the basis of hypothesis 3 which posited that the two trauma groups but in particular the PTSD group in comparison with healthy controls would retain less information after a period of sleep in comparison with baseline scores. The retention scores of depressed participants were hypothesized to fall between that of the PTSD and healthy control group. I also hypothesized that there would be no group differences in terms of procedural memory.

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This study did not replicate previous research that shows deficits in immediate recall for declarative memory in PTSD (Bremner, Randall, Scott, Bronen, et al., 1995; Bremner, et al., 1993; Gil, et al., 1990; Gilbertson, et al., 2001; Jenkins, et al., 1998; Vasterling, et al., 1998; Yehuda, et al., 1995) - neither the VPA nor the LM encoding scores showed that PTSD participants performed worse than the other groups. This result may be accounted for by the relatively small sample and at best moderate effect sizes reported for encoding measures, while a meta-analysis of several studies examining declarative memory performance (based on encoding or immediate recall scores only) found that the effect size derived from the results of PTSD diagnosed participants that experienced sexual abuse was 0.54. Thus the effect size reported in my study is substantially lower than that of previous research. The reasons for this difference in effect size between this study and previous research is unclear.

In terms of delayed declarative recall, limited support was found for hypothesis 2. Both LM-MORN and the AMT showed that trauma-exposed non-PTSD participants in comparison to healthy controls performed more poorly on recall of story information from the previous night as well as recall of specific autobiographical memories. However on neither of these tests did PTSD participants perform more poorly than healthy controls. Although research has widely reported deficits in delayed declarative memory recall in PTSD (Brandes, et al., 2002; Bremner, Randall, Scott, Capelli, et al., 1995; Bremner, et al., 1993; Gilbertson, et al., 2001; Jenkins, et al., 1998; Vasterling, et al., 1998; Vasterling, et al., 2000; Vasterling, et al., 2002), this finding has been specific to PTSD diagnosed participants and not to trauma-exposed non-PTSD participants. However few studies examining delayed declarative recall in PTSD have used both a trauma-exposed non-PTSD and healthy control group, limiting the ability to discern between trauma-exposure and the adverse psychological reaction to trauma (PTSD). A more detailed discussion with regard to this point may be found below.

In terms of declarative memory retention some support was found for hypothesis 3. Participants diagnosed with PTSD retained significantly less story information for LM% than healthy controls. Although results did not reach statistical significance, trends also showed that trauma-exposed non-PTSD participants retained less information than healthy controls. However I did not find similar results for VPA% - that is neither PTSD nor trauma-exposed non-PTSD participants recalled fewer word pairs than healthy controls.

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The analysis of the retention of declarative information is at the centre of this study, since the retention represents how much participants remembered in comparison to what they encoded after a period of sleep. Described more fully, the retention scores represent the delayed recall of information after the memory consolidation process has occurred during sleep and initial encoding scores have been taken into account. Thus this score is implicitly measuring the effectiveness of memory consolidation, since previous findings have shown that sleep benefits memory and actively works to solidify memory traces (Marshall & Born, 2007).

Although this study cannot answer questions surrounding anatomical structure, it is hypothesized that hippocampal functioning underlies the deficits in declarative memory retention observed in PTSD participants in comparison with healthy controls. Previous research has shown that the hippocampus is volumetrically smaller in individuals diagnosed with PTSD (Bremner & Narayan, 1998; Bremner, et al., 1997; Bremner, et al., 2003; Gilbertson, et al., 2002; Smith, 2005; Villarreal, et al., 2002; Vythilingam, et al., 2005) and that its activation pattern is different in PTSD (Werner, et al., 2009). Also the hippocampus is particularly active during sleep in what has been termed the off-line processing of memory traces (Bodizs, et al., 2002; Ji & Wilson, 2007; Louie & Wilson, 2001; Marshall & Born, 2007). The results of this study showing decreased memory retention in PTSD diagnosed participants after sleep speculatively suggest that the hippocampal dependent memory consolidation process during sleep is disrupted in individuals diagnosed with PTSD. Further research is needed to investigate this hypothesis including more subtle questions such as whether a damaged hippocampus is unable to perform its processing tasks during sleep or whether disrupted sleep impairs the functioning of the hippocampus or an interaction of the two.

However some caution needs to be exercised when interpreting these results since the percentage of retention only implies the role of sleep and memory consolidation – it is possible that individuals diagnosed with PTSD simply forget more readily given a period of time in comparison with healthy controls – that is PTSD diagnosed individuals' memory degrades more readily over time than that of healthy controls. However the literature suggests results to the contrary – almost all studies found that individuals diagnosed with PTSD did not show memory degradation for declarative memory over a period of wakefulness in comparison with controls when initial immediate recall scores had been taken into account (Brandes et al., 2002; Stein et al., 1999; Stein et al, 2002; Sullivan et al., 2003; Vasterling et al., 1998, 2002; Vasterling,

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Brailey et al., 2000). Thus the findings in this study suggest that the decrease in memory retention observed in PTSD participants in comparison with healthy controls is likely to be the product of poor memory consolidation during sleep, since other studies have not found decreases in memory retention during wakefulness.

Further, in terms of exercising caution, the decrease in memory retention observed in PTSD participants was only found for LM% and not for VPA% - that is results are not consistent across measures measuring a similar construct. The meaning of this discrepancy between LM% and VPA% is unclear. It is possible that these two variables measure somewhat different aspects of declarative memory – that is the VPA test measures the ability to remember neutral facts, while the LM test measures memory for narrative about characters and events and that individuals diagnosed with PTSD process different kinds of information differently. However no conclusions can be drawn from the current research to answer this discrepancy - more research is needed to clarify whether deficits in declarative memory retention are specific only to some aspects of declarative memory in PTSD.

In terms of procedural memory no between-group differences were found, either in immediate recall, delayed recall or the percentage of retention. This result is important in that it highlights that the memory differences found are limited to declarative memory and are not global changes in memory functioning.

Specific between-group differences. Once again the question arises as to whether deficits in declarative memory in the PTSD literature are specific to PTSD or the experience of trauma. The delayed recall findings for LM and AMT both found that only the trauma-exposed non-PTSD participants performed more poorly than healthy controls. This result is somewhat confusing in that PTSD participants have also experienced trauma – if an experience of trauma rather than PTSD per se informs declarative memory deficits then *both* the PTSD and trauma-exposed non-PTSD participants should perform more poorly in comparison with healthy controls on measures of declarative memory recall. The current data suggest that since only trauma-exposed non-PTSD participants performed more poorly than healthy controls, that a PTSD diagnosis offers a protective factor against poor declarative memory recall, which is strongly counter-intuitive. A more likely reason for the results observed is that my data had limited power, based on a small sample, to elucidate the full range of group differences. Both for measures of LM-MORN and AMT, the PTSD group had a similar mean to that of the trauma-

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exposed non-PTSD group (see Table 9) indicating that differences between these two groups are small.

The LM% variable was clearer in explaining the difference between PTSD and trauma exposure for declarative memory retention. Broadly speaking, both participants from the PTSD and trauma-exposed non-PTSD groups showed poorer declarative memory retention than healthy controls (although the results between the trauma-exposed non-PTSD and healthy control groups only approached significance); however analyses did not reveal any differences between PTSD and trauma-exposed non-PTSD participants. This result suggests that trauma-exposure rather than PTSD per se results in poorer declarative memory retention.

More research is needed to clarify the role of trauma exposure in all aspects of declarative memory in the PTSD literature, although taken together the results outlined above do hint at a specific role for trauma exposure rather than PTSD. Interestingly a meta-analysis of several studies examining declarative memory performance found that the effect size derived from comparing PTSD participants to trauma-exposed non-PTSD participants across all studies, specifically for sexual abuse, was almost negligible (d = 0.001). However this was not the case for other sources of trauma such as war were the effect size derived from comparing these two groups across all studies was large (d = 0.75). Further the effect sizes derived from comparing PTSD participants to (a) healthy controls and (b) all controls specifically for sexual abuse were both substantial (d = 0.62 and d = 0.54 respectively). Thus the results from this meta-analysis suggest that specifically for sexual abuse or sexual crime, trauma experience rather than a diagnosis of PTSD informs poor declarative memory performance in comparison with controls. Although the reasons for this finding are unknown and certainly warrant further investigation, the results from my study are in alignment with the findings from the meta-analysis.

In terms of differentiating depression from PTSD and trauma-exposure for declarative memory, results from this study are inconsistent. Three entirely different results were obtained for three measures of declarative memory (VPA, LM and AMT). For VPA-EVE (immediate recall for word pairs) depressed participants recalled significantly less word pairs in comparison with trauma-exposed non-PTSD participants. However for VPA% (retention of word pairs) depressed participants retained significantly more word pairs than trauma-exposed non-PTSD participants. For LM%, which showed other between-group differences already mentioned depression seemed to play no role as depressed participants did not score better or worse than

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any of the groups. In contrast, for the AMT measure, depressed participants recalled significantly more specific memories than the trauma-exposed non-PTSD participants. Taken together these results are inconsistent bearing in mind that they are all describing the same construct of declarative memory. Further research is needed to tease apart the current picture.

Summarizing memory findings. In summary, contrary to previous research the PTSD participants did not show poorer immediate recall for measures of declarative memory in comparison with healthy controls. However for both for the LM stories and the AMT, trauma-exposed participants recalled less information than healthy controls, providing limited support for Hypothesis 2. However, the most interesting finding thus far was that PTSD participants, after baseline measures had been taken into account, retained less information in comparison with healthy controls after sleep, in part confirming hypothesis 3. This finding is important in that implies that the memory consolidation process during sleep is disrupted in PTSD although this result was not consistent over different measures of declarative memory retention. Further the analysis showed that these results are specific to declarative memory and not procedural memory, suggesting that specifically the hippocampal memory consolidation process is disrupted.

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Hypothesis 4: Relating observed sleeping patterns to memory deficits

The previous section showed support for the hypothesis that individuals diagnosed with PTSD would retain significantly less information after a period of sleep (hypothesis 3). However as mentioned before the results only imply the role of sleep and memory consolidation – further analysis was conducted to determine whether (a) disordered sleeping patterns predicted poor declarative memory performance and (b) whether disordered sleeping patterns mediated group membership in predicting poor memory performance – that is do individuals who have been diagnosed with PTSD that sleep poorly have declarative memory and retention deficits (hypothesis 4).

For the regression analyses run on the data from LM-MORN, LM percent retention, and AMT total score, of the sleep-related variables only SWS percentage emerged as a predictor of post-sleep declarative memory delayed recall (i.e., LM-MORN). For that analysis, IQ, depression severity, group membership in the trauma-exposed non-PTSD versus the healthy control group, and SWS percentage were statistically significant predictors of memory

performance. More specifically, the final model for LM-MORN suggested that individuals with relatively lower IQs, and who experience depressive symptoms, and who have experienced trauma, and who, in addition to all of these factors, have a higher-than-normal percentage of SWS, are at greater risk for performing more poorly on a delayed recall declarative memory task.

The first point of interest here is that SWS percentage only served as a predictor for declarative memory recall in combination with the other predictors, that is, SWS percentage on its own did not predict performance on declarative memory recall task. This piece of data indicates that SWS percentage is an *additional* risk factor for poor memory performance, but that by itself it has little to no predictive power. Even more noteworthy, perhaps, is that for SWS percentage to predict memory performance, group membership is also necessary: that is, SWS percentage is only relevant for individuals who have had an experience of trauma.

The second point of interest here is that the analysis of LM-MORN showed that an increase in SWS percentage is associated with poorer declarative memory recall, that is, more SWS resulted in poorer recall. This result seems contradictory to previous research showing that more SWS *benefits* declarative memory consolidation. However, as described in the section on sleep-related variables, disordered sleep in individuals who have experienced trauma can be characterised by both increases *and* decreases in sleep characteristics, such as SWS percentage. Because other authors have found both increases and decreases in SWS percentage in PTSD diagnosed participants (Pillar, et al., 2000), it is feasible to understand an increase in SWS percentage as a marker of disordered sleep. Thus, it is not contradictory for individuals who have experienced trauma and who have an increase in SWS percentage to have relatively impaired performance on tasks of declarative memory recall.

None of the analyses showed mediational effects – that is sleep variables did not mediate group membership for any of the declarative memory domains. However bearing in mind that sleep latency, the number of spontaneous arousals and SWS percentage only approached significance for group differences, and this analysis aimed to predicting group-based memory performance from sleep variables, this result is not unexpected.

Overall, only SWS percentage predicted declarative memory recall when in combination with other factors. Sleep variables did not mediate group membership for memory recall and retention, probably due to the lack of significant group differences for sleep variables. Thus hypothesis 4 was supported only in part.

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Other findings. For the delayed recall measures of declarative memory – LM-MORN and AMT, significant predictors included IQ and depression, but not symptom severity. It is a well established fact that memory performance and IQ measures are related (Salthouse, 2003), so this result is expected. It is also reasonable that depression will affect memory scores since depression is marked by a lack of motivation and drive and both trauma groups were similarly depressed.

Once IQ and depression had been controlled for, both regression analyses showed that membership in the trauma-exposed rather than control group predicted poor declarative memory recall. Thus being in the trauma-exposed group had an negative influence on delayed declarative recall, implying that trauma exposure rather than a diagnosis of PTSD results in poor declarative memory recall. Once again this finding may seem confusing in that PTSD participants are also trauma-exposed and therefore membership in both the PTSD and trauma-exposed non-PTSD groups should predict poor memory performance. Recall, however, that the between-group differences analysis of LM-MORN and AMT (ANOVA analysis) found that only trauma-exposed non-PTSD participants had poorer declarative memory recall in comparison with healthy controls, interpreted largely as a product of limited power in the current analysis for LM-MORN and AMT. Since ANOVA is another way of doing regression analysis (Field, 2009) this result has simply been replicated in the regression analyses.

It is also important to note the role of depression as a predictor in declarative memory performance. Although the analysis for LM% showed that the role of depression is unclear due to problems of multicollinearity, both the analysis of LM-MORN and AMT reflected depression as an important predictor of declarative memory recall. For LM-MORN depression shared a similar portion of the variance as group membership (belonging to the trauma-exposed or healthy control group; depression: 9.9%; group membership: 7.6%) indicating that both symptoms of depression and trauma-exposure play a similar role in determining declarative memory recall. For AMT, depression was the most significant factor explaining 15.4% of the variance while group membership (belonging to the trauma-exposed or healthy control group) only explained 5.4%. This finding suggests that depression is a more salient predictor than trauma experience in determining specific autobiographical recall. Other studies have also found that overgeneralised autobiographical memory recall is more closely associated with either depression or a combination of PTSD and depression (Vasterling and Brailey, 2005) since studies have not

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observed overgeneralised memory recall in PTSD participants free of depression. Overall these findings show that comorbid depression should not be taken for granted when determining the influence of PTSD or trauma on memory and reiterate the importance of controlling for comorbid depression.

Limitations and Directions for Future Research

This study showed many methodological strengths, controlling for many variables which previous studies failed to adequately address. However some methodological aspects can be improved on. This study had a small sample which in some cases may have limited my ability to elucidate the relationships hypothesized. This is particularly true for the more detailed group differences – such as the difference between the trauma and depressed groups and the difference between trauma-exposed and PTSD participants. A larger sample may also clarify group differences in sleep quality – our analysis showed that sleep latency, the number of spontaneous arousals and SWS percentage approached significance with medium effect sizes indicating that a small increase in sample may clarify the significance of these tests. Furthermore the power for these analyses was moderate (sleep latency: 0.53; number of spontaneous arousals: 0.58 SWS percentage: 0.53) lending further support for an increase in sample.

This study also included a number of individuals that were HIV positive. Although these individuals were asymptomatic, HIV in its later stages is associated with neurocognitive decline and it is possible that that more subtle changes associated with the disease may have influenced results. Due to constraints with recruitment and the relatively high exclusion rate associated with stringent controls these individuals were included in the study on the basis that they were asymptomatic.

This research suggested some promising avenues for further investigation. In the realm of sleep and PTSD more research is needed to explain the inconsistent findings across various studies. Although this research project addressed many of the methodological shortfalls of previous studies eliminating many potential covariates the results show similar results to many other studies – that is sleep only tends to be worse in PTSD. Since subjective reports posit that sleep is severely affected in PTSD, more research is needed to address this discrepancy. This study suggests that future research in PTSD focuses on the possible mechanism of oscillation

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between hyperarousal and sleep compensation states to address discrepancies in objective sleep measures.

Future research should also clarify the role of depression as an influence on sleep and memory in PTSD. Similarly the difference between trauma-exposure and PTSD needs further clarification to determine whether it is the experience of trauma alone or the psychologically maladaptive response to trauma (PTSD) that precipitates disordered sleep and memory deficits.

However most strikingly this study showed support for the hypothesis that memory consolidation during sleep is disrupted in PTSD. This finding needs more investigation, both in replication and in more sophisticated investigation. This research is in its infancy and future research needs to address some important questions. Firstly a replication of this study should include an awake control group to control for the effect of sleep. A control group that remains awake between the before and after memory measures will show whether the same degeneration in memory traces occurs while awake. This will clarify the role of sleep – whether memory consolidation is indeed disrupted during sleep specifically. Although other research studies have shown that PTSD participants do not retain less information than controls while awake this should be systematically controlled for. This study was limited in time and resources and could thus not address this issue.

Further fMRI studies during sleep may be useful in observing hippocampal activity during sleep. Since it is hypothesized that the memory consolidation disruption is underpinned by hippocampal changes, imaging studies will clarify the role of this anatomical structure and help build a theoretical understanding of the relationship between sleep and memory in PTSD.

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CONCLUSION

This study showed some support for the hypothesis that memory consolidation is disrupted during sleep in PTSD. PTSD participants retained significantly less information on a declarative memory task than healthy controls after sleep, despite the fact that individuals in this group did not show the worst encoding or delayed recall scores. Further disruptions in SWS, which is directly implicated in declarative memory consolidation during sleep, predicted poor memory performance in at least one domain of declarative memory. Together these results highlight the importance of sleep in memory functioning for individuals diagnosed with PTSD –

that is sleep has wider implications than just the inability to fall asleep and maintain sleep. Further this research has shown that symptoms do not exist in isolation but influence each other – a topic that as yet is little explored.

REFERENCES

(A.P.A.), A. P. A. (2000). *Diagnostic and statistical manual of mental disorders* (Vol. 4th edition., text revision). Washington, DC: American Psychiatric Association.

AASM (2007). The AASM manual for the scoring of sleep and associated events. In 2007 (Ed.): American Academy of Sleep Medicine.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corporation.

Blackman, M. R. (2000). Age-related alterations in sleep quality and neuroendocrine function: interrelationships and implications. *Journal of the American Medical Association, 284*(7), 879-881.

Blake, D. D., Weathers, W., Nagy, L. M., Kaloupek, D. G., Gusman, F. D., Charney, D. S., et al. (1995). The development of a clinician-administered PTSD scale. *Journal of Traumatic Stress, 8*, 75-90.

Bodizs, R., Bekesy, M., Szucs, A., Barsi, P., & Halasz, P. (2002). Sleep-dependent hippocampal slow activity correlates with waking memory performance in humans. *Neurobiology, Learning and Memory, 78*(2), 441-457.

Brandes, D., Ben-Schachar, G., Gilboa, A., Bonne, O., Freedman, S., & Shalev, A. Y. (2002). PTSD symptoms and cognitive performance in recent trauma survivors. *Psychiatry Research, 110*(3), 231-238.

Bremner, J. D., Krystal, J. H., Southwick, S. M., & Charney, D. S. (1995). Functional neuroanatomical correlates of the effects of stress on memory. *Journal of Traumatic Stress, 8*(4), 527-553.

Bremner, J. D., & Narayan, M. (1998). The effects of stress on memory and the hippocampus throughout the life cycle: implications for childhood development and aging. *Developmental Psychopathology, 10*(4), 871-885.

Bremner, J. D., Randall, P., Scott, T. M., Bronen, R. A., Seibyl, J. P., Southwick, S. M., et al. (1995). MRI-based measurement of hippocampal volume in patients with combat-related posttraumatic stress disorder. *American Journal of Psychiatry, 152*(7), 973-981.

University of Cape Town

Bremner, J. D., Randall, P., Scott, T. M., Capelli, S., Delaney, R., McCarthy, G., et al. (1995). Deficits in short-term memory in adult survivors of childhood abuse. *Psychiatry Research, 59*(1-2), 97-107.

Bremner, J. D., Randall, P., Vermetten, E., Staib, L., Bronen, R. A., Mazure, C., et al. (1997). Magnetic resonance imaging-based measurement of hippocampal volume in posttraumatic stress disorder related to childhood physical and sexual abuse--a preliminary report. *Biological Psychiatry, 41*(1), 23-32.

Bremner, J. D., Scott, T. M., Delaney, R. C., Southwick, S. M., Mason, J. W., Johnson, D. R., et al. (1993). Deficits in short-term memory in posttraumatic stress disorder. *American Journal of Psychiatry, 150*(7), 1015-1019.

Bremner, J. D., Vythilingam, M., Vermetten, E., Southwick, S. M., McGlashan, T., Nazeer, A., et al. (2003). MRI and PET study of deficits in hippocampal structure and function in women with childhood sexual abuse and posttraumatic stress disorder. *American Journal of Psychiatry, 160*(5), 924-932.

Carey, P. D., Stein, D. J., Zungu-Dirwayi, N., & Seedat, S. (2003). Trauma and posttraumatic stress disorder in an urban Xhosa primary care population: prevalence, comorbidity, and service use patterns. *Journal of Nervous Mental Disorders, 191*(4), 230-236.

Carrier, J., Land, S., Buysse, D. J., Kupfer, D. J., & Monk, T. H. (2001). The effects of age and gender on sleep EEG power spectral density in the middle years of life (ages 20-60 years old). *Psychophysiology, 38*(2), 232-242.

Chokroverty, S. (2009a). An overview of normal sleep. In S. Chokroverty (Ed.), *Sleep disorders medicine* (pp. 5-23). Philadelphia, PA Saunders Elsevier.

Chokroverty, S. (2009b). Sleep deprivation and sleepiness. In S. Chokroverty (Ed.), *Sleep disorders medicine* (pp. 22-28). Philadelphia, PA: Saunders Elsevier.

Constans, J. I. (2005). Information-processing biases in PTSD. In J. J. Vasterling & C. R. Brewin (Eds.), *Neuropsychology of PTSD* (pp. 105-130). Newy York, NY: The Guilford Press.

Corporation, T. P. (1998). *Wechsler Memory Scale - Third Revision* San Antonio: Texas: Harcourt Brace & Company.

Corporation, T. P. (1999). *Wechsler Abbreviated Scale of Intelligence*. San Antonio, Texas: Harcourt Brace & Company.

University of Cape Town

Dagan, Y., Lavie, P., & Bleich, A. (1991). Elevated awakening thresholds in sleep stage 3-4 in war-related post-traumatic stress disorder. *Biological Psychiatry, 30*(6), 618-622.

Dagan, Y., Zinger, Y., & Lavie, P. (1997). Actigraphic sleep monitoring in posttraumatic stress disorder (PTSD) patients. *Journal of Psychosomatic Research, 42*(6), 577-581.

De Bellis, M. D., Hooper, S. R., & Sapia, J. L. (2005). Early trauma exposure and the brain. In J. J. Vasterling & C. R. Brewin (Eds.), *Neuropsychology of PTSD* (pp. 153-177). New York, NY: The Guilford Press.

Dow, B. M., Kelsoe, J. R., Jr., & Gillin, J. C. (1996). Sleep and dreams in Vietnam PTSD and depression. *Biological Psychiatry, 39*(1), 42-50.

Engdahl, B. E., Eberly, R. E., Hurwitz, T. D., Mahowald, M. W., & Blake, J. (2000). Sleep in a community sample of elderly war veterans with and without posttraumatic stress disorder. *Biological Psychiatry, 47*(6), 520-525.

Field, A. (2009). *Discoveringstatistics using SPSS* (Third Edition ed.). London: Sage.

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. (1997). *Structured Clinical Interview for DSM-IV Axis I Disorders-Clinician Version (SCID-CV).* Washington, DC: American Psychiatric Press.

Fischer, S., Hallschmid, M., Elsner, A. L., & Born, J. (2002). Sleep forms memory for finger skills. *Proc Natl Acad Sci U S A, 99*(18), 11987-11991.

Franzen, P. L., & Buysse, D. J. (2009). Sleep in psychiatric disorders In S. Chokroverty (Ed.), *Sleep disorders medicine* (pp. 538-549). Philadelphia, PA: Saunders Elsevier.

Fuller, K. H., Waters, W. F., & Scott, O. (1994). An investigation of slow-wave sleep processes in chronic PTSD patients. *Journal of Anxiety Disorders, 8,* 227-236.

Gais, S., Plihal, W., Wagner, U., & Born, J. (2000). Early sleep triggers memory for early visual discrimination skills. *Natural Neuroscience, 3*(12), 1335-1339.

Galea, S., Ahern, J., Nandi, A., Tracy, M., Beard, J., & Vlahov, D. (2007). Urban neighborhood poverty and the incidence of depression in a population-based cohort study. *Annals of Epidemiology, 17*(3), 171-179.

Gaudreau, H., Carrier, J., & Montplaisir, J. (2001). Age-related modifications of NREM sleep EEG: from childhood to middle age. *Journal of Sleep Research, 10*(3), 165-172.

Germain, A., & Nielsen, T. A. (2003). Sleep pathophysiology in posttraumatic stress disorder and idiopathic nightmare sufferers. *Biological Psychiatry, 54*(10), 1092-1098.

University of Cape Town

Gil, T., Calev, A., Greenberg, D., Kugelmass, S., & Lerer, B. (1990). Cognitive functioning in posttraumatic stress disorder. *Journal of traumatic stress, 3*, 29-45.

Gilbertson, M. W., Gurvits, T. V., Lasko, N. B., Orr, S. P., & Pitman, R. K. (2001). Multivariate assessment of explicit memory function in combat veterans with posttraumatic stress disorder. *Journal of Traumatic Stress, 14*(2), 413-432.

Gilbertson, M. W., Shenton, M. E., Ciszewski, A., Kasai, K., Lasko, N. B., Orr, S. P., et al. (2002). Smaller hippocampal volume predicts pathologic vulnerability to psychological trauma. *Natural Neuroscience, 5*(11), 1242-1247.

Glaubman, H. M., Miculincer, M., Porat, A., Wasserman, O., & Birger, M. (1990). Sleep of chronic posttraumatic patients. *Journal of Traumatic Stress, 3*, 255-256.

Gurvits, T. V., Gilbertson, M. W., Lasko, N. B., Orr, S. P., & Pitman, R. K. (1997). Neurological status of combat veterans and adult survivors of sexual abuse PTSD. *Annals of the New York Academy of Science, 821*, 468-471.

Harvey, A. G., & Bryant, R. A. (1998). The relationship between acute stress disorder and posttraumatic stress disorder: a prospective evaluation of motor vehicle accident survivors. *Journal of Consulting Clinical Psychology, 66*(3), 507-512.

Harvey, A. G., Jones, C., & Schmidt, D. A. (2003). Sleep and posttraumatic stress disorder: a review. *Clinical Psychology Review, 23*(3), 377-407.

Hefez, A., Metz, L., & Lavie, P. (1987). Long-term effects of extreme situational stress on sleep and dreaming. *American Journal of Psychiatry, 144*(3), 344-347.

Herbst, E., Metzler, T. J., Lenoci, M., McCaslin, S. E., Inslicht, S., Marmar, C. R., et al. Adaptation effects to sleep studies in participants with and without chronic posttraumatic stress disorder. *Psychophysiology, 47*(6), 1127-1133.

Hoban, T. (2009). Evolution of sleep from birth through adolescence, and sleep disordered breathing in children. In S. Chokroverty (Ed.), *Sleep disorders medicine* (pp. 630-643). Philadelphia, PA: Saunders Elsevier.

Hofmann, S. G., Litz, B. T., & Weathers, F. W. (2003). Social anxiety, depression, and PTSD in Vietnam veterans. *Journal of Anxiety Disorders, 17*(5), 573-582.

Holbrook, T. L., Hoyt, D. B., Stein, M. B., & Sieber, W. J. (2002). Gender differences in long-term posttraumatic stress disorder outcomes after major trauma: women are at higher risk of adverse outcomes than men. *Journal of Trauma, 53*(5), 882-888.

University of Cape Town

Hurwitz, T. D., Mahowald, M. W., Kuskowski, M., & Engdahl, B. E. (1998). Polysomnographic sleep is not clinically impaired in Vietnam combat veterans with chronic posttraumatic stress disorder. *Biological Psychiatry, 44*(10), 1066-1073.

Jenkins, M. A., Langlais, P. J., Delis, D., & Cohen, R. (1998). Learning and memory in rape victims with posttraumatic stress disorder. *American Journal of Psychiatry, 155*(2), 278-279.

Ji, D., & Wilson, M. A. (2007). Coordinated memory replay in the visual cortex and hippocampus during sleep. *Natural Neuroscience, 10*(1), 100-107.

Kales, A., Kales, J. D., Sly, R. M., Scharf, M. B., Tan, T. L., & Preston, T. A. (1970). Sleep patterns of asthmaticchildren: all-night electroencephalographic studies. *Journal of Allergy, 46*(5), 300-308.

Kali, S., & Dayan, P. (2004). Off-line replay maintains declarative memories in a model of hippocampal-neocortical interactions. *Natural Neuroscience, 7*(3), 286-294.

Kaminer, D., Grimsrud, A., Myer, L., Stein, D. J., & Williams, D. R. (2008). Risk for post-traumatic stress disorder associated with different forms of interpersonal violence in South Africa. *Social Science Medicine, 67*(10), 1589-1595.

Kaminer, H., & Lavie, P. (1991). Sleep and dreaming in Holocaust survivors. Dramatic decrease in dream recall in well-adjusted survivors. *Journal of Nervous Mental Disorders, 179*(11), 664-669.

Keenan, S. (2009). Polysomnographic technique: an overview. In S. Chokroverty (Ed.), *Sleep disorders medicine* (pp. 137-156). Philadelphia, PA: Saunders Elsevier.

Kessler, R. C., Sonnega, A., Bromet, E., Hughes, M., & Nelson, C. B. (1995). Posttraumatic stress disorder in the National Comorbidity Survey. *Archives of General Psychiatry, 52*(12), 1048-1060.

Kirschbaum, C., Wust, S., & Hellhammer, D. (1992). Consistent sex differences in cortisol responses to psychological stress. *Psychosom Med, 54*(6), 648-657.

Klein, E., Koren, D., Arnon, I., & Lavie, P. (2002). No evidence of sleep disturbance in post-traumatic stress disorder: a polysomnographic study in injured victims of traffic accidents. *Isr J Psychiatry Relat Sci, 39*(1), 3-10.

Kobayashi, I., Boarts, J. M., & Delahanty, D. L. (2007). Polysomnographically measured sleep abnormalities in PTSD: a meta-analytic review. *Psychophysiology, 44*(4), 660-669.

University of Cape Town

Koren, D., Arnon, I., Lavie, P., & Klein, E. (2002). Sleep complaints as early predictors of posttraumatic stress disorder: a 1-year prospective study of injured survivors of motor vehicle accidents. *Am J Psychiatry, 159*(5), 855-857.

Kosten, T. R., Mason, J. W., Giller, E. L., Ostroff, R. B., & Harkness, L. (1987). Sustained urinary norepinephrine and epinephrine elevation in post-traumatic stress disorder. *Psychoneuroendocrinology, 12*(1), 13-20.

Krakow, B., Schrader, R., Tandberg, D., Hollifield, M., Koss, M. P., Yau, C. L., et al. (2002). Nightmare frequency in sexual assault survivors with PTSD. *J Anxiety Disord, 16*(2), 175-190.

Kramer, M., & Kinney, L. (1988). Sleep patterns in trauma victims with disturbed dreaming. *Psychiatr J Univ Ott, 13*(1), 12-16.

Lavie, P., Hefez, A., Halperin, G., & Enoch, D. (1979). Long-term effects of traumatic war-related events on sleep. *Am J Psychiatry, 136*(2), 175-178.

Lavie, P., Katz, N., Pillar, G., & Zinger, Y. (1998). Elevated awaking thresholds during sleep: characteristics of chronic war-related posttraumatic stress disorder patients. *Biol Psychiatry, 44*(10), 1060-1065.

Le Bon, O., & Arpi, S. (2003). [Effect of the first sleep night in polysomnography: classification by variable sensitivity and factorial analysis of differences between nights]. *Rev Neurol (Paris), 159*(11 Suppl), 6S42-47.

Louie, K., & Wilson, M. A. (2001). Temporally structured replay of awake hippocampal ensemble activity during rapid eye movement sleep. *Neuron, 29*(1), 145-156.

Lupien, S., Gillin, C. J., & Hauger, R. L. (1999). Working memory is more sensitive than declarative memory to the acute effects of corticosteroids: a dose-response study in humans. *Behav Neurosci, 113*(3), 420-430.

Lupien, S., Lecours, A. R., Lussier, I., Schwartz, G., Nair, N. P., & Meaney, M. J. (1994). Basal cortisol levels and cognitive deficits in human aging. *J Neurosci, 14*(5 Pt 1), 2893-2903.

Maquet, P. (2001). The role of sleep in learning and memory. *Science, 294*(5544), 1048-1052.

Marshall, L., & Born, J. (2007). The contribution of sleep to hippocampus-dependent memory consolidation. *Trends Cogn Sci, 11*(10), 442-450.

McEwen, B. S. (1999). Stress and the aging hippocampus. *Front Neuroendocrinol, 20*(1), 49-70.

University of Cape Town

Mellman, T. A., Bustamante, V., Fins, A. I., Pigeon, W. R., & Nolan, B. (2002). REM sleep and the early development of posttraumatic stress disorder. *Am J Psychiatry, 159*(10), 1696-1701.

Mellman, T. A., David, D., Bustamente, V., Torres, J., & Fins, A. (2001). Dreams in the acute aftermath of trauma and their relationship to PTSD. *Journal of Traumatic Stress, 14*, 241-247.

Mellman, T. A., David, D., Kulick-Bell, R., Hebding, J., & Nolan, B. (1995). Sleep disturbance and its relationship to psychiatric morbidity after Hurricane Andrew. *American Journal of Psychiatry, 152*(11), 1659-1663.

Mellman, T. A., Kulick-Bell, R., Ashlock, L. E., & Nolan, B. (1995a). Sleep events among veterans with combat-related posttraumatic stress disorder. *American Journal of Psychiatry, 152*(1), 110-115.

Mellman, T. A., Kulick-Bell, R., Ashlock, L. E., & Nolan, B. (1995b). Sleep events among veterans with combat-related posttraumatic stress disorder. *Am J Psychiatry, 152*(1), 110-115.

Mellman, T. A., Kumar, A., Kulick-Bell, R., Kumar, M., & Nolan, B. (1995). Nocturnal/daytime urine noradrenergic measures and sleep in combat-related PTSD. *Biological Psychiatry, 38*(3), 174-179.

Mellman, T. A., Nolan, B., Hebding, J., Kulick-Bell, R., & Dominguez, R. (1997). A polysomnographic comparison of veterans with combat-related PTSD, depressed men, and non-ill controls. *Sleep, 20*(1), 46-51.

Neylan, T. C., Marmar, C. R., Metzler, T. J., Weiss, D. S., Zatzick, D. F., Delucchi, K. L., et al. (1998). Sleep disturbances in the Vietnam generation: findings from a nationally representative sample of male Vietnam veterans. *Am J Psychiatry, 155*(7), 929-933.

Ohayon, M. M., & Shapiro, C. M. (2000). Sleep disturbances and psychiatric disorders associated with posttraumatic stress disorder in the general population. *Compr Psychiatry, 41*(6), 469-478.

Pillar, G., Malhotra, A., & Lavie, P. (2000). Post-traumatic stress disorder and sleep-what a nightmare! *Sleep Medicine Review, 4*(2), 183-200.

Plihal, W., & Born, J. (1997). Effects of early and late nocturnal sleep on declarative and procedural memory. *Journal of cognitive neuroscience, 9*, 534-547.

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PsychologySoftwareTools (2002) (Version Version 1.1). Pittsburgh, PA.

Rauchs, G., Desgranges, B., Foret, J., & Eustache, F. (2005). The relationships between memory systems and sleep stages. *J Sleep Res, 14*(2), 123-140.

Riege, W. H., Holloway, J. A., & Kaplan, D. W. (1981). Specific memory deficits associated with prolonged alcohol abuse. *Alcohol Clin Exp Res, 5*(3), 378-385.

Roehrs, T., & Roth, T. (2001). Sleep, sleepiness, sleep disorders and alcohol use and abuse. *Sleep Medicine Review, 5*(4), 287-297.

Ross, R. J., Ball, W. A., Dinges, D. F., Kribbs, N. B., Morrison, A. R., Silver, S. M., et al. (1994). Rapid eye movement sleep disturbance in posttraumatic stress disorder. *Biological Psychiatry, 35*(3), 195-202.

Saki, K. (1991). Physiological properties and afferent connections of the locus coeruleus and adjacent tegmental neurons involved in the generation of paradoxical sleep in the cat. *Progressive Brain Research, 88*, 31-45.

Salthouse, T. A. (2003). Memory aging from 18 to 80. *Alzheimer Dis Assoc Disord, 17*(3), 162-167.

Saltzman, K. M., Weems, C. F., & Carrion, V. G. (2006). IQ and posttraumatic stress symptoms in children exposed to interpersonal violence. *Child Psychiatry and Human Development, 36*(3), 261-272.

Schreuder, B. J., Klein, W. C., & Rooijmans, H. C. (2000). Nocturnal re-experiencing more than forty years after war trauma

Journal of Traumatic Stress, 13, 453-463.

Selzer, M. L. (1971). The Michigan Alcoholism Screening Test: The quest for a new diagnostic instrument. *American Journal of Psychiatry, 127*, 1653-1658.

Sforza, E., Chapotot, F., Pigeau, R., & Buguet, A. (2008). Time of night and first night effects on arousal response in healthy adults. *Clinical Neurophysiology, 119*(7), 1590-1599.

Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E., et al. (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *Journal of Clinical Psychiatry, 59*, 22-33.

Smith, M. E. (2005). Bilateral hippocampal volume reduction in adults with post-traumatic stress disorder: a meta-analysis of structural MRI studies. *Hippocampus, 15*(6), 798-807.

University of Cape Town

Squire, L. R., Ojemann, J. G., Miezin, F. M., Petersen, S. E., Videen, T. O., & Raichle, M. E. (1992). Activation of the hippocampus in normal humans: a functional anatomical study of memory. *Proc Natl Acad Sci U S A, 89*(5), 1837-1841.

Stein, M. B., Hanna, C., Vaerum, V., & Koverola, C. (1999). Memory functioning in adult women traumatized by childhood sexual abuse. *Journal of Traumatic Stress, 12*(3), 527-534.

Stein, M. B., Kennedy, C. M., & Twamley, E. W. (2002). Neuropsychological function in female victims of intimate partner violence with and without posttraumatic stress disorder. *Biological Psychiatry, 52*(11), 1079-1088.

Stewart, S. H., Pihl, R. O., Conrod, P. J., & Dongier, M. (1998). Functional associations among trauma, PTSD, and substance-related disorders. *Addictive Behaviour, 23*(6), 797-812.

Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature, 437*(7063), 1272-1278.

Stickgold, R., James, L., & Hobson, J. A. (2000). Visual discrimination learning requires sleep after training. *Natural Neuroscience, 3*(12), 1237-1238.

Sullivan, K., Krengel, M., Proctor, S. P., Devine, S., Heeren, T., & White, R. F. (2003). Cognitive Functioning in Treatment-Seeking Gulf War Veterans: Pyridostigmine Bromide Use and PTSD *Journal of psychopathology and behavioural assessment, 25*, 95-103.

Uddo, M., Vasterling, J. J., Brailey, K., & Sutker, P. B. (1993). Memory and attention in post-traumatic stress disorder. *Journal of psychopathology and behavioural assessment, 15*(43-52).

Uttl, B., Graf, P., & Richter, L. K. (2002). Verbal Paired Associates tests limits on validity and reliability. *Archives of Clinical Neuropsychology, 17*(6), 567-581.

van der Kolk, B., Blitz, R., Burr, W., Sherry, S., & Hartmann, E. (1984). Nightmares and trauma: a comparison of nightmares after combat with lifelong nightmares in veterans. *American Journal of Psychiatry, 141*(2), 187-190.

Vasterling, J. J., & Brailey, K. (2005). Neuropsychological findings in adults with PTSD. In J. J. Vasterling & C. R. Brewin (Eds.), *Neuropsychology of PTSD* (pp. 182-184). New York, NY: The Guilford Press.

Vasterling, J. J., Brailey, K., Constans, J. I., & Sutker, P. B. (1998). Attention and memory dysfunction in posttraumatic stress disorder. *Neuropsychology, 12*(1), 125-133.

University of Cape Town

Vasterling, J. J., Brailey, K., & Sutker, P. B. (2000). Olfactory identification in combat-related posttraumatic stress disorder. *Journal of Traumatic Stress, 13*(2), 241-253.

Vasterling, J. J., Duke, L. M., Brailey, K., Constans, J. I., Allain, A. N., Jr., & Sutker, P. B. (2002). Attention, learning, and memory performances and intellectual resources in Vietnam veterans: PTSD and no disorder comparisons. *Neuropsychology, 16*(1), 5-14.

Vermetten, E., Vythilingam, M., Southwick, S. M., Charney, D. S., & Bremner, J. D. (2003). Long-term treatment with paroxetine increases verbal declarative memory and hippocampal volume in posttraumatic stress disorder. *Biological Psychiatry, 54*(7), 693-702.

Villarreal, G., Hamilton, D. A., Petropoulos, H., Driscoll, I., Rowland, L. M., Griego, J. A., et al. (2002). Reduced hippocampal volume and total white matter volume in posttraumatic stress disorder. *Biological Psychiatry, 52*(2), 119-125.

Vythilingam, M., Luckenbaugh, D. A., Lam, T., Morgan, C. A., 3rd, Lipschitz, D., Charney, D. S., et al. (2005). Smaller head of the hippocampus in Gulf War-related posttraumatic stress disorder. *Psychiatry Research, 139*(2), 89-99.

Walker, M. P., Brakefield, T., Hobson, J. A., & Stickgold, R. (2003). Dissociable stages of human memory consolidation and reconsolidation. *Nature, 425*(6958), 616-620.

Walker, M. P., & Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. *Neuron, 44*(1), 121-133.

Walker, M. P., Stickgold, R., Alsop, D., Gaab, N., & Schlaug, G. (2005). Sleep-dependent motor memory plasticity in the human brain. *Neuroscience, 133*(4), 911-917.

Weathers, F. W., Keane, T. M., & Davidson, J. R. (2001). Clinician-administered PTSD scale: a review of the first ten years of research. *Depression and Anxiety, 13*(3), 132-156.

Wechsler, D. (1987). *Wechsler Memory-Scale Revised manual*. San Antonio: The Psychological Corporation.

Werner, N. S., Meindl, T., Engel, R. R., Rosner, R., Riedel, M., Reiser, M., et al. (2009). Hippocampal function during associative learning in patients with posttraumatic stress disorder. *Journal of Psychiatry Research, 43*(3), 309-318.

Williams, J., & Broadbent, K. (1986). Autobiographical memory in suicide attempters. *Journal of Abnormal Psychology, 95*, 144-149.

University of Cape Town

Woodward, S. H., Friedman, M. J., & Bliwise, D. L. (1996). Sleep and depression in combat-related PTSD inpatients. *Biological Psychiatry, 39*(3), 182-192.

Yehuda, R., Keefe, R. S., Harvey, P. D., Levengood, R. A., Gerber, D. K., Geni, J., et al. (1995). Learning and memory in combat veterans with posttraumatic stress disorder. *American Journal of Psychiatry, 152*(1), 137-139.

Yehuda, R., Southwick, S., Giller, E. L., Ma, X., & Mason, J. W. (1992). Urinary catecholamine excretion and severity of PTSD symptoms in Vietnam combat veterans. *Journal of Nervous Mental Disorders, 180*(5), 321-325.

Yetkin, S., Aydin, H., & Ozgen, F. (2010). Polysomnography in patients with post-traumatic stress disorder. *Psychiatry and Clinical Neuroscience, 64*(3), 309-317.

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Appendix A

Socio- Economic Status and Demographic Questionnaire

1. Age: _____

2. Sex (circle one): Male Female

3. What is your home language? (Please circle only *one* option)

   English Afrikaans Xhosa Zulu Pedi

   Other (please specify _____

4. What is the total monthly income of the household in which you live? If you are a student please take care to put your immediate caregiver's monthly income, not your own. (Please circle only *one* option):

R0 – R499	R500 – R999	R1000 – R2499
R2500 – R5499	R5500 – R9999	R10 000+

5. Occupation (please circle appropriate letter):
   (a) Unemployed
   (b) Self-employed
   (c) Business employed
   (d) Student/pupil
   (e) Other (*Specify*) _____

6. Education: Highest degree or grade completed: _____

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Appendix B

The VPA list of word paired- associates- immediate recall (evening task)

Trial 1

Rose (flower)	
Fruit (apple)	
Room (face)	
Coal (year)	
Metal (iron)	
School (grocery)	
Hill (ring)	
Frog (neck)	
Cabbage (pen)	
Bank (milk)	
Girl (sign)	
Obey (inch)	
Foot (tree)	
Baby (cries)	
Crush (dark)	

Trial 2

Obey (inch)	
Bank (milk)	
Hill (ring)	
Crush (dark)	
Coal (year)	
Room (face)	
Foot (tree)	
Girl (sign)	
Baby (cries)	
Metal (iron)	
Frog (neck)	
Fruit (apple)	
Rose (flower)	
School (grocery)	
Cabbage (pen)	

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The VPA list of word paired- associates- delayed recall (morning task)

Metal (iron)	
Coal (year)	
Obey (inch)	
Baby (cries)	
Room (face)	
Bank (milk)	
Rose (flower)	
Foot (tree)	
Frog (neck)	
Cabbage (pen)	
School (grocery)	
Crush (dark)	
Hill (ring)	
Fruit (apple)	
Girl (sign)	

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Appendix C

Autobiographical Memory Test

1. Happy			
☐	☐		☐
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		

2. Failure			
☐	☐		☐
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		

3. Rhythm			
☐	☐		☐
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		

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A

4. Relieved

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

5. Guilty

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

6. Shoes

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

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A

7. Joy			
▢	▢		▢
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

8. Helpless			
▢	▢		▢
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

9. Tree			
▢	▢		▢
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

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A

10. Devoted

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

11. Rejected

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

12. Uncle

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

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13. Tender

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

14. Sad

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

15. Library

❒	❒		❒
❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response	❒ specific ❒ extended ❒ categoric ❒ sem ass ❒ no response		
Prompt for clarification ❒			

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Appendix D

Subjective report of sleep at the laboratory

1) Were you asleep when I came in?
2) How did you sleep?
3) Did you sleep better, normal or worse in comparison with how you usually sleep?
    a. Better = 2
    b. Normal = 1
    c. Worse = 0
4) Why?
5) Did the equipment bother you?
    a. Yes = 1
    b. No = 2
6) Do you remember any dreams?
7) Did you wake up during the night?
8) How often?
9) Estimate how long you actually slept for (as opposed to how long you spent in bed)
10) From the time I switched off the lights, how long did it take for you to fall asleep?

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Appendix E:

Informed consent form

Informed Consent to Participate in Research and Authorization for Collection, Use, and Disclosure of Sleep Patterns, Performance on Memory tasks and Other Personal Data

You are being asked to take part in a research study. This form provides you with information about the study and seeks your authorization for the collection, use and disclosure of your sleep architecture patterns, cognitive performance data, as well as other information necessary for the study. The Principal Investigator (the person in charge of this research) or a representative of the Principal Investigator will also describe this study to you and answer all of your questions. Your participation is entirely voluntary. Before you decide whether or not to take part, read the information below and ask questions about anything you do not understand. For your information – this study is covered by UCT's No Fault Insurance Policy.

1. Name of Participant ("Study Subject")

_____

2. Title of Research Study
"The Relationship between Sleep and Memory in Post-Traumatic Stress Disorder."

3. Principal Investigator and Telephone Number(s)

Malgorzata Lipinska
University of Cape Town
Contact number: 084 621 0683

4. What is the purpose of this research study?

This research aims to investigate the whether disrupted sleep helps to explain memory problems in Post Traumatic Stress Disorder

5. What will be done if you take part in this research study?

In this experiment, you will be called in for a sleep study on 3 nights and MRI brain scans after the sleep studies have been carried out.

Before commencing the actual study, you will undergo a screening process whereby the Principal Investigator listed in # 3 of this form or her assistant, will administer a number of short psychiatric questionnaires and an IQ test. They are merely research instruments that allow us to identify certain patterns of interest.

We will also take a comprehensive medical history from you where we will ask you to provide us with details of any medication you are currently on and any other things we should be aware of

The sleep study will be arranged at least one week in advance, at a time convenient to you. Transport will be provided. You will retain your routine bedtime and waking time but will be asked to avoid caffeine and sugar in your diet for a few hours before bedtime. You will be required to come to the sleep laboratory based at Vincent Pallotti Private Hospital between 19 30 and 20 00 and will be briefed once more, in detail, on the procedure. You will be hooked to a polysomnograph (PSG) which is an EEG machine designed to monitor your sleep pattern. Electrodes will be placed on your head, chest, near your chin and temples; these are completely safe and present no danger whatsoever to your health. They are designed to transmit physiological indications of the stage of sleep you

are experiencing at a given point in time, to a computer monitor. One or two researchers will be surveilling the monitor in an adjoining room. They will be available to you for assistance at any time. There is a panic button at your bedside should you need assistance at any point during the night.

One the first night you will simply sleep the whole night through uninterrupted. In the morning the electrodes will be removed and you will be given a lift back home.

On the second night you will arrive at the same time. This time before going to sleep you will be presented with some material that is part of a memory exercise. After learning the material you will be connected up to the PSG and will sleep for 3 hours. After three hours you will be woken up and asked to do some of the memory exercises again. They will not take longer than fifteen minutes, after which you will return to sleep for the remainder of the night.

On the third night once again you will arrive between 19 30 and 20 00. This time round you will be connected up to the PSG first and will sleep for three hours on arrival. After three hours you will be woken up and presented with some memory exercises, after which you will return back to sleep. On waking in the morning you will again be presented with the memory exercises. The experiment typically ends at 08 00 on the following morning.

After the sleep sessions are over, you will be informed in detail about the design of the study and the research questions we hope to address with this study. You will also have the opportunity to ask questions and thus learn more about psychological research. If you have any questions now or at any time during the study, you may contact the Principal Investigator listed in #3 of this form.

In addition after the sleep sessions we will together arrange a time for the MRI brain scans to be done. The reason for these scans is to relate certain brain structures known to be involved in memory to the research questions at hand

6. If you choose to participate in this study, how long will you be expected to participate in the research?

Screening and interview session: approximately 2 hrs and sleep study: 3 nights only over three weeks – that is one session per week. Plus one additional meeting of about 2 hours for the MRI scan.

7. How many people are expected to participate in the research?

80

8. What are the possible discomforts and risks?

Sleeping in an environment other than your own bedroom might feel strange and uncomfortable at first. Great precautions will be taken to ensure your safety and comfort. The sleep laboratory at Vincent Pallotti is fully equipped with a proper bed, clean bedding, restrooms and a kitchenette. It is situated in a secure building with adequate surveillance and alarm system. Attempts will be made to familiarise you with the PSG and the electrodes used will be padded and lubricated so as to be as non-intrusive as possible. Although the whole process will not delve deep into past memories and traumatic events experienced, if any difficult memories should arise during the process, you will be referred to trained clinicians for extra guidance.

In terms of the MRI scan, there are associated risks which will be explained in details before the scan. You are also provided with information on MRI and the scanning process which explains the associated risks and discomforts.

10a. What are the possible benefits to you?

You may or may not personally benefit from participating in this study. Participation in this study may, however, improve your understanding of some factors that affect sleep and may influence your management of your health generally.

10b. What are the possible benefits to others?

The information from this study may help improve our understanding of the importance of sleep. This study aims to show that symptoms do not exist in isolation but influence each other. If it is indeed the case that difficulties in sleeping are related to difficulties in memory then we know we need to focus more on addressing sleeping patterns. In fact some research has shown that if you improve sleeping patterns other symptoms also improve and this study hopes to elaborate on this.

11. If you choose to take part in this research study, will it cost you anything?

Participating in this study will not cost you anything.

12. Will you receive compensation for taking part in this research study?

You will receive financial compensation of the amount of R150 for each night you sleep in the laboratory. Thus if you participate in the research for 3 nights you will receive R450.

13a. Can you withdraw from this research study?

You are free to withdraw your consent and to stop participating in this research study at any time. If you do withdraw your consent, there will be no penalty.

If you have any questions regarding your rights as a research subject, you may phone the Psychology Department offices at 021-650-3430.

13b. If you withdraw, can information about you still be used and/or collected?

Information already collected may be used.

14. Once personal and performance information is collected, how will it be kept secret (confidential) in order to protect your privacy?

Information collected will be stored in locked filing cabinets or in computers with security passwords. Only certain people have the right to review these research records. These people include the researchers for this study and certain University of Cape Town officials. Your research records will not be released without your permission unless required by law or a court order.

15. What information about you may be collected, used and shared with others?

This information gathered from you will be demographic information, information on a past traumatic event and the related diagnosis of post traumatic stress disorder and/or depression, records of your sleep architecture, performance on cognitive tests, and scores on the IQ test and psychiatric inventory. If you agree to be in this research study, it is possible that some of the information collected might be copied into a "limited data set" to be used for other research purposes. If so, the limited data set may only include information that does not directly identify you. For example, the limited data set **cannot** include your name, address, telephone number, ID number, or any other photographs, numbers, codes, or so forth that link you to the information in the limited data set.

16. How will the researcher(s) benefit from your being in the study?

In general, presenting research results helps the career of a scientist. Therefore, the Principal Investigator and others attached to this research project may benefit if the results of this study are presented at scientific meetings or in scientific journals. This study is being undertaken for the Principal Investigator's masters degree.

17. Signatures

As a representative of this study, I have explained to the participant the purpose, the procedures, the possible benefits, and the risks of this research study; and how the participant's performance and other data will be collected, used, and shared with others:

Signature of Person Obtaining Consent and Authorization Date

_____ _____

You have been informed about this study's purpose, procedures, possible benefits, and risks; and how your performance and other data will be collected, used and shared with others. You have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time.

You voluntarily agree to participate in this study. You hereby authorize the collection, use and sharing of your performance and other data. By signing this form, you are not waiving any of your legal rights.

Signature of Person Consenting and Authorizing Date

_____ _____

Please indicate below if you would like to be notified of future research projects conducted by our research group: _____ (initial) Yes, I would like to be added to your research participation pool and be notified of research projects in which I might participate in the future.

Method of contact:

Phone number: _____
E-mail address: _____
Mailing address: _____
_____
_____

Appendix F

Histogram's of distribution of sleep variables

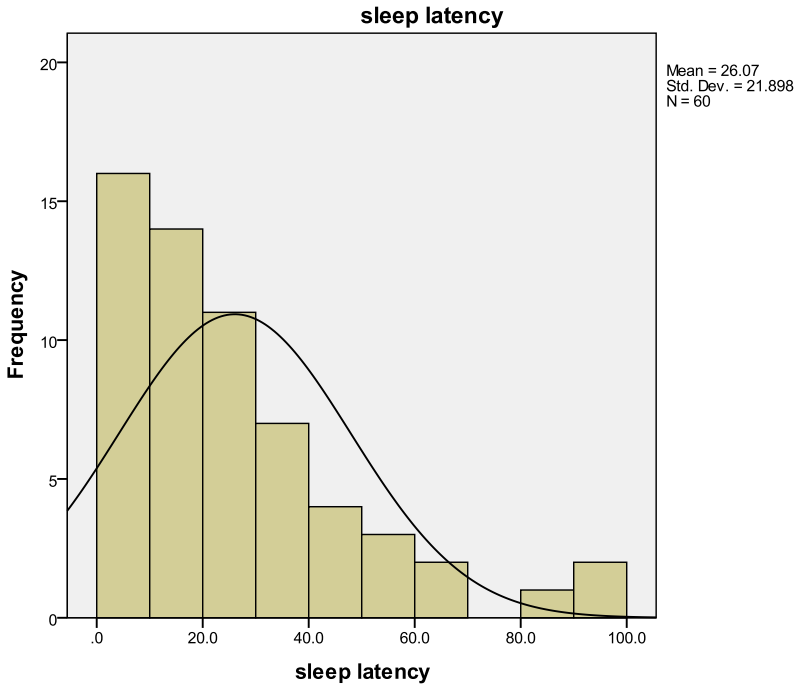

Figure F1: Distribution of sleep latency for total sample.

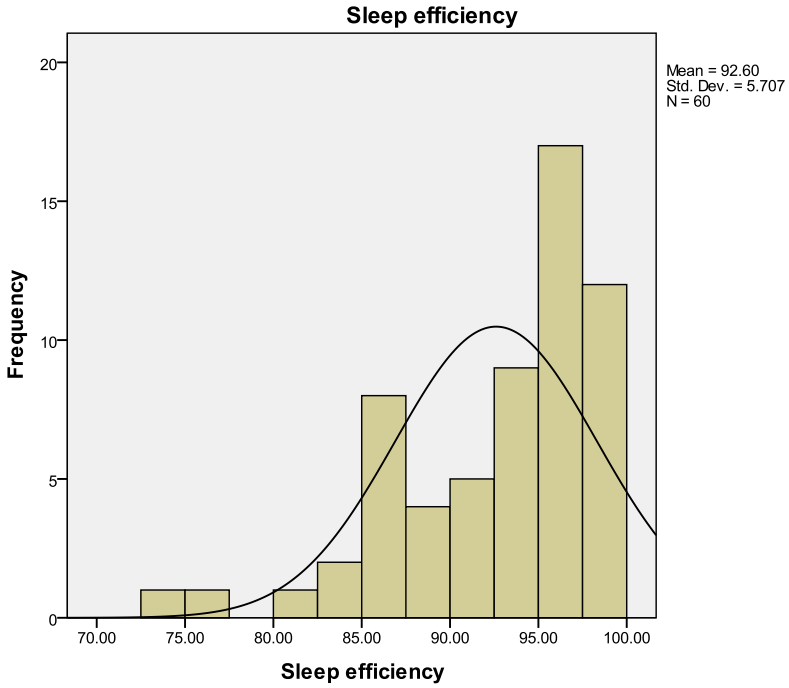

Figure F2: Distribution of sleep efficiency for total sample.

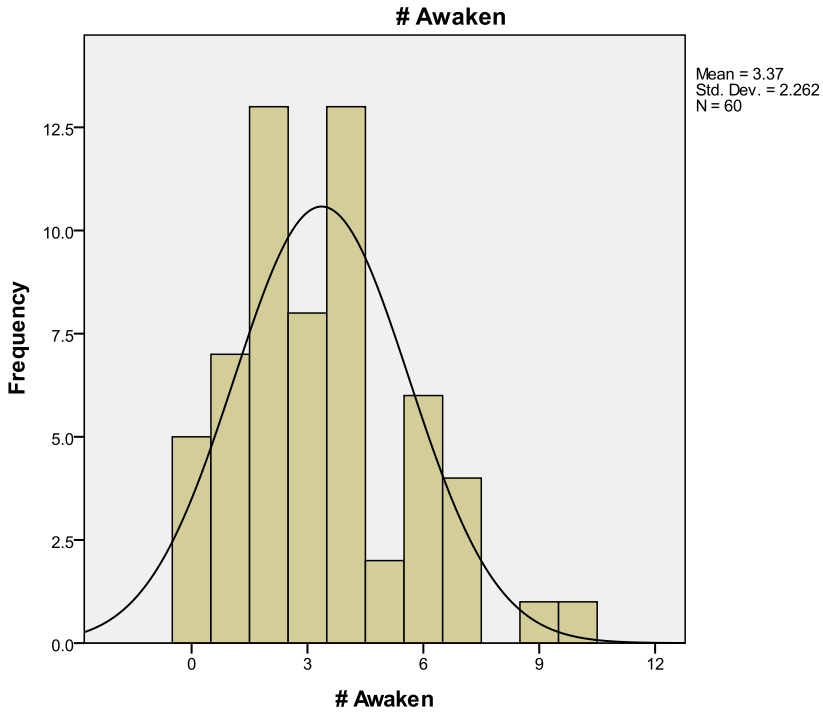

Figure F3: Distribution of the number of awakenings for total sample.

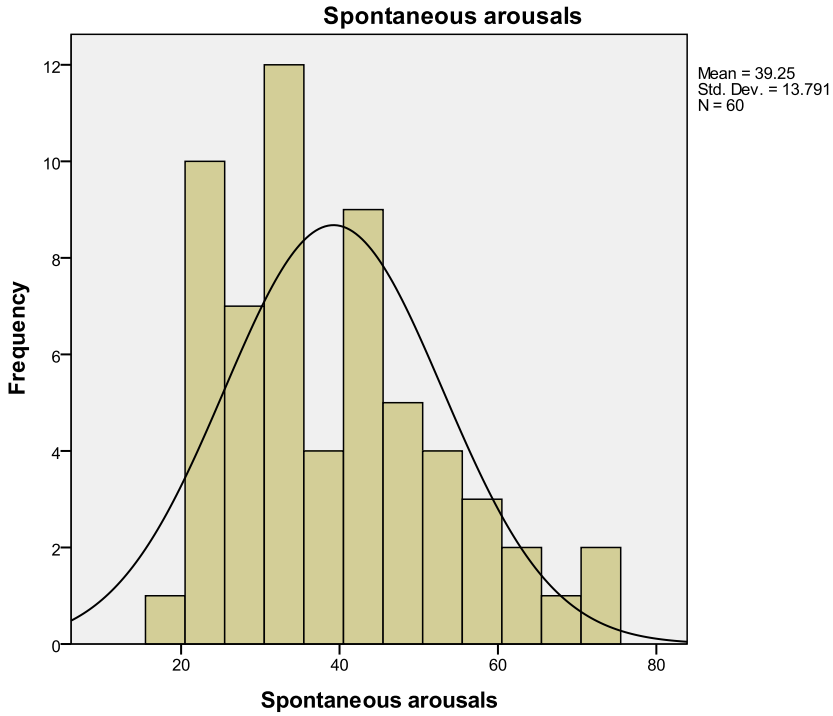

Figure F4: Distribution of the number of spontaneous arousals for total sample

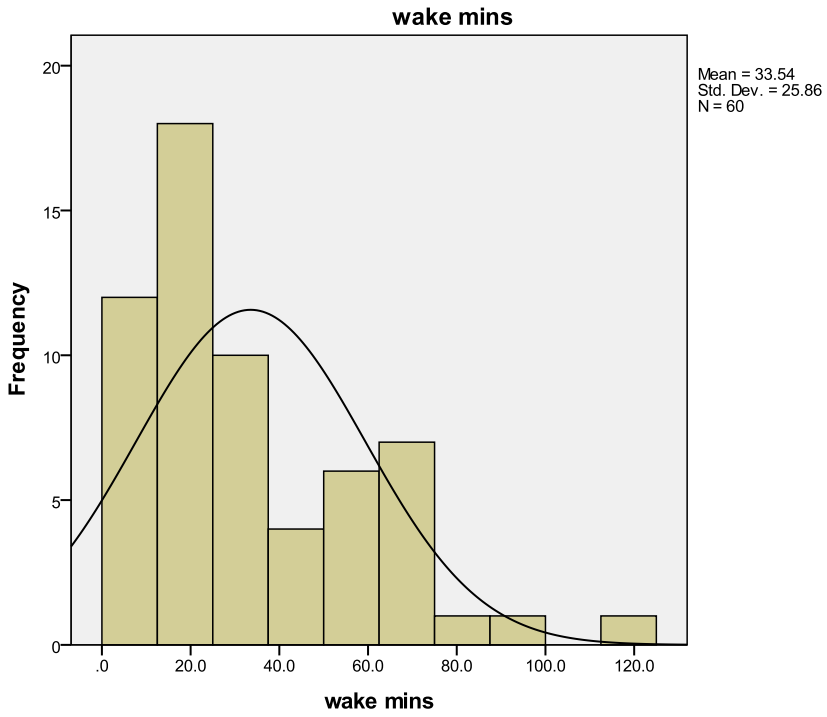

Figure F5: Distribution of time spent awake after sleep onset for total sample

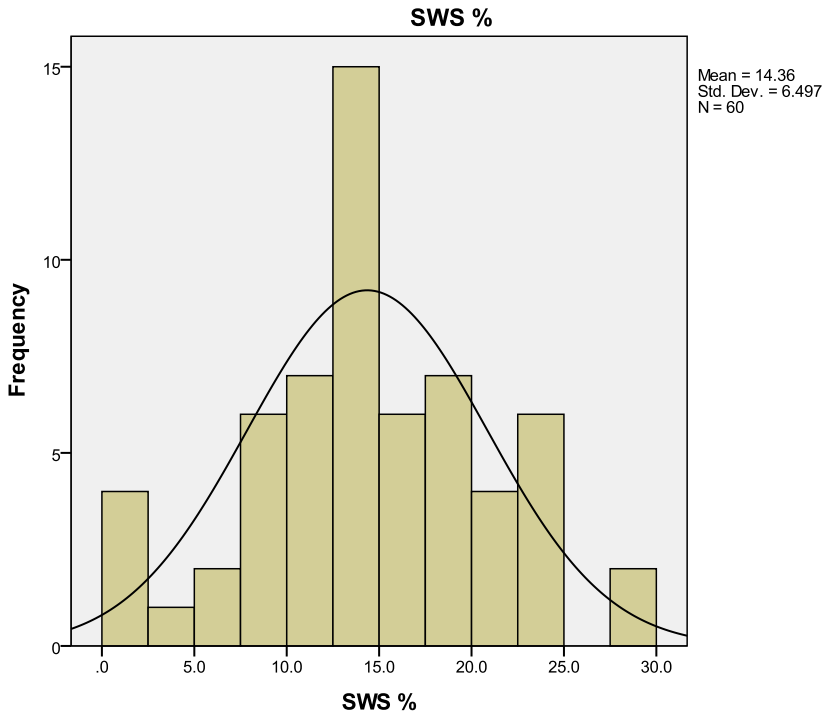

Figure F6: Distribution of SWS percentage for total sample

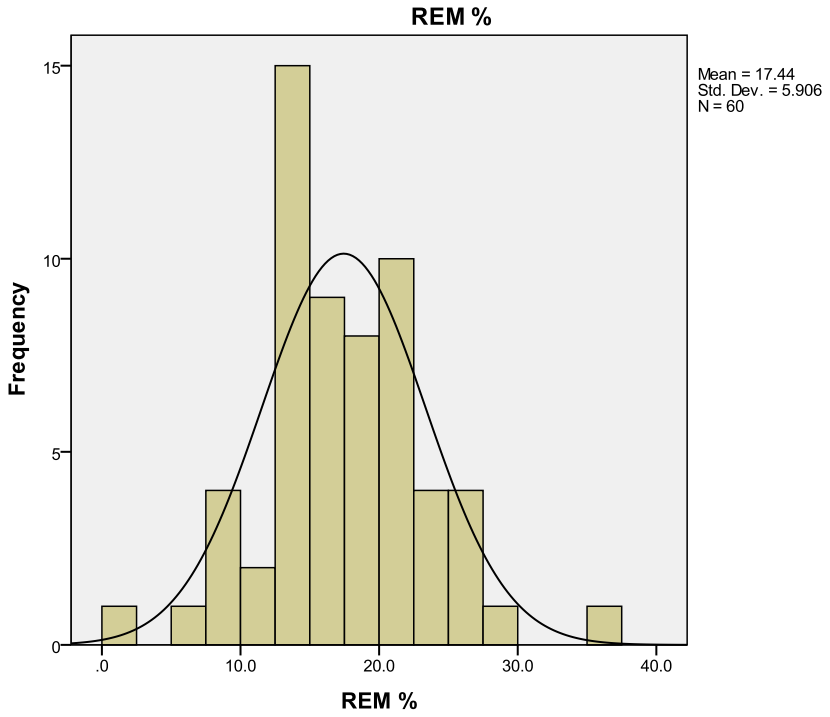

Figure F7: Distribution of REM percentage for total sample

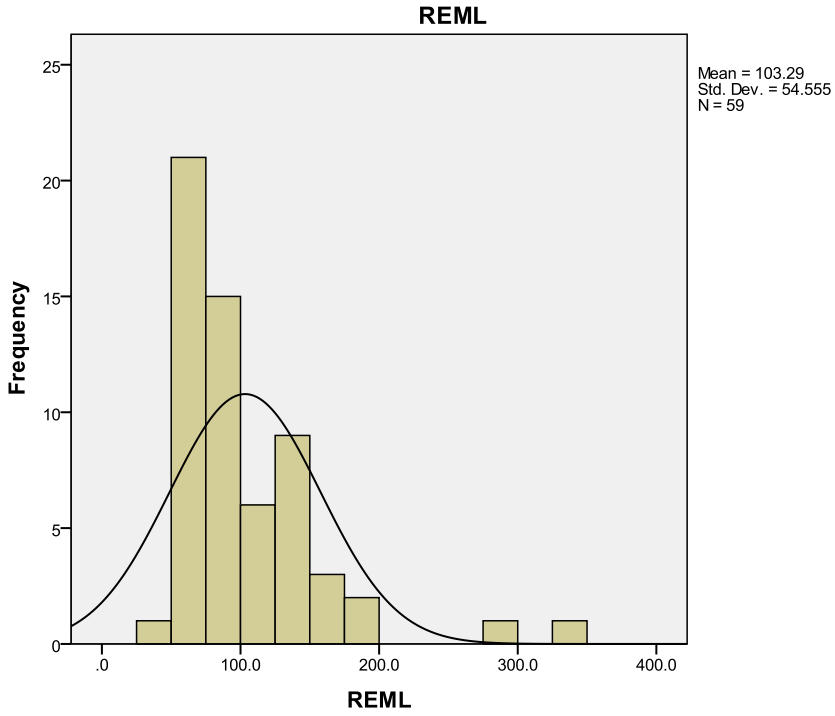

Figure F8: Distribution of REM latency for total sample